# Accident Potential: An Ontario Driver Records Study Technical Report

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Safety Co-ordination & Development Office
Research & Evaluation Section

Ministry of Transportation
Ontario

# Accident Potential: An Ontario Driver Records Study Technical Report

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Protecting Our Environment
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# ABSTRACT

The current demerit point system in use in Ontario allocates points to offences on the basis of the perceived seriousness of the offence. The goal of the work reported here was to allocate points to offences with a different purpose in mind. The purpose here was to use a driver's record of convictions and accidents in order to predict, as well as possible, which drivers, based on their past record, are most likely to have an accident in the near future.

A sample of 827,955 records of Ontario drivers containing information about age, gender, convictions, accidents, demerit points and suspensions, for 1981-1984 was examined. On this basis 16 new models to estimate a driver's accident potential were formulated. Some models used age and gender information, others did not. Some models assigned different weights to each of the conviction categories; in other models all convictions were weighted equally (equivalent to 1 point per conviction). In some models accident data were used; in other models, not. In contrast to the current system, information on all types of convictions, not just moving convictions, was used. It turns out that these new models are better at predicting a driver's accident potential than the current demerit point system.

The performance of the new models is described by means of two measures. The first measure is the number of accidents in period 2 (1983-1984) based on the driver's record of convictions and accidents in period 1 (1981-1982). For example, if the 10,000 drivers with the **most demerit points** in period 1 are selected, 1452 have accidents in period 2; if the 10,000 drivers with the **most accidents** in period 1 are selected, 1828 have accidents in period 2. Alternatively, if the 10,000 drivers are selected on the basis of the **best new model**, which uses age, gender, accidents and separate weights for 14 offence categories, 2116 have accidents in period 2.

The second measure of performance is in terms of "hits" and "false alarms". "Hits" are drivers who have an accident potential in excess of 4 times the population average. For example, if the 10,000 drivers with the highest estimated accident potential are selected by the best model, 3757 of these are are expected to be "hits". "False alarms" are drivers who have an accident potential which is below the population average. Of the same 10,000, one should expect 792 to be "false alarms". The best model identifies approximately twice as many high accident potential drivers as the current demerit point system. Even the simplest model, which uses total convictions as the only variable, predicts 50% more high accident potential drivers than the current system.

# ABRÉGÉ

L'actuel système de points d'inaptitude en usage en Ontario donne des points aux infractions en fonction de la gravité qu'on leur attribue. Dans le travail qui nous occupe ici, il s'agissait de donner des points aux infractions dans un but différent, plus précisément, de se baser sur le dossier des condamnations et accidents des conducteurs pour prédire le mieux possible lesquels ont le plus de chances d'avoir un accident dans un avenir proche.

On a donc examiné un échantillon de 827 955 dossiers de conducteurs ontariens, contenant des renseignements sur l'âge, le sexe, les condamnations, les accidents, les points d'inaptitude et les suspensions de permis de 1981 à 1984. À partir de ces données, on a établi 16 nouveaux modèles censés évaluer les chances d'accident d'un conducteur. Certains modèles intégraient les données sur l'âge et le sexe, d'autres pas. Certains modèles pondéraient les diverses catégories de condamnations et d'autres les traitaient toutes sur le même pied (un point par condamnation, quelle que soit la nature du délit). Certains modèles intégraient les données sur les accidents et d'autres pas. Contrairement au système actuel, ces modèles tenaient compte de tous les types de condamnations, et non uniquement de celles portant sur des infractions commises par les conducteurs de véhicules en marche. Il s'est avéré que ces nouveaux modèles arrivent à mieux prédire les chances d'accident d'un conducteur que l'actuel système de points d'inaptitude.

Les résultats des nouveaux modèles apparaissent dans deux mesures. La première est le nombre d'accidents pendant la période 2 (1983-1984) en fonction du dossier des condamnations et accidents du conducteur pendant la période 1 (1981-1982). Par exemple, si l'on retient les 10 000 conducteurs qui ont eu le plus de points d'inaptitude pendant la période 1, on trouve que 1 452 d'entre eux ont des accidents pendant la période 2; si l'on retient les 10 000 conducteurs qui ont eu le plus d'accidents pendant la période 1, on trouve que 1 828 d'entre eux ont des accidents pendant la période 2. Selon l'autre méthode, si la sélection des 10 000 conducteurs s'effectue selon le meilleur nouveau modèle, basé sur l'âge, le sexe, les accidents et 14 catégories d'infractions de poids différents, on trouve que 2 116 d'entre eux ont des accidents pendant la période 2.

La deuxième mesure classe les conducteurs en «récidivistes» et «fausses alertes». Les récidivistes sont les conducteurs qui ont des chances d'accident supérieures à quatre fois celles de la population moyenne. Par exemple, si les 10 000 conducteurs qui ont le plus de chances d'accident sont sélectionnés par le meilleur modèle, 3 757 d'entre eux sont classés comme «récidivistes». Les «fausses alertes» sont les conducteurs qui ont des chances d'accident inférieures à celles de la population moyenne. Sur les 10 000 conducteurs cités ci-dessus, on devrait en trouver 792. Le meilleur modèle permet d'identifier environ deux fois plus de conducteurs ayant des chances élevées d'accident que l'actuel système de points d'inaptitude. Même le modèle le plus simple, dont la seule variable est le nombre total de condamnations, identifie 50 % de plus de conducteurs ayant des chances élevées d'accident que l'actuel système.

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## 1.0 INTRODUCTION

The current demerit point system in use in Ontario allocates points to offenses on the basis of the perceived seriousness of the offense. An offense is considered serious if it is associated with a relatively large chance of precipitating an accident. This is why a non-moving violation, such as not having a trailer permit, receives no points, while running a red light receives a lot of points. The goal of the work described in this report was to allocate points to offenses with a different purpose in mind. The purpose here was to use a driver's record of convictions and accidents in order to estimate as well as possible which drivers, based on their past record, are most likely to have an accident in the near future. This is done by calculating for each driver how many accidents per year he or she is likely to have, on the average.

Because a person's "accident potential" can only be indirectly estimated (not directly measured) and because, mercifully, for any one driver it is rare to be involved in an accident, the accuracy with which we can estimate the accident potential of a driver is bound to be severely circumscribed. Thus, our aim is not only to produce for each driver an estimate of his or her accident potential but also to say how accurate our estimate is.

This is the kind of knowledge which might then be used in the determination of post-licensing control action. Thus, while a non-moving violation may not be a threat to traffic safety, such a conviction on a driver's record may be an important clue about that person's likelihood of future accidents.

## 2.0 DRIVER RECORD SAMPLE

The analysis examined driver records over a recent four-year period, January 1981 to December, 1984. Convictions and accidents during the first two years of the record were used as the basis for estimating a person's accident potential in the second two-year period.

To be included in the sample, drivers had to have been licensed to drive in Ontario throughout the four-year period. To this end, a number of criteria were used in the selection of driver records. These criteria were as follows. First, drivers not licensed at the beginning of the study period were excluded. Second, drivers who might have moved out of Ontario during the four year period were excluded. These exclusions were achieved by only selecting drivers who renewed their drivers' license during 1985, with the exception of those who were 16 or 17 in 1981. This exception was made because such a large percentage of drivers become licensed at 16 and 17, that the majority of drivers of this age would be renewing their licenses in 1984 (3 years after the original licensing) and would have been excluded from the sample. Because drivers had to have been licensed in 1987 to be included in this study, no drivers on the new probationary license system were included.

Of the 5.5 million Ontario drivers, 827,995 met these criteria and were included in the sample. Data extracted from the MTO driver records included the following information: age, gender, and for each conviction, type, date, and demerit points assigned; for each accident, degree of severity, date, and for each suspension, type and time period. Details are shown in Table 1.

TABLE 1 Summary of data extracted from MTO driver records

**1. Root Segment** (33 characters)

| Field # | Width | Description |
|---|---|---|
| 1.1 | 15 | License Number |
| 1.2 | 3 | License Class |
| 1.3 | 3 | Total Demerit Points at Time of "Dump" |
| 1.4 | 6 | Original Date of License (YY-MM-DD) |
| 1.5 | 6 | Date of Last Renewal (YY-MM-DD) |

**2. Conviction Segment** (Space for 75 convictions at 22 characters per conviction

| Field # | Width | Description |
|---|---|---|
| 2.1 | 6 | Conviction Offence Date (YY-MM-DD) |
| 2.2 | 5 | " " Code |
| 2.3 | 3 | Recorded Speed for Speeding Convictions |
| 2.4 | 3 | Speed Limit " " " |
| 2.5 | 3 | Conviction Demerit Points |
| 2.6 | 1 | Code = 1 for Personal Injury, = 2 for Property Damage, 3 for Fatality, associated with conviction. |
| 2.7 | 1 | Code = 1 if partial points applied, Ø otherwise. |

**3. Suspension Segment** (Space for 2Ø Suspensions at 15 characters per suspension

| Field # | Width | Description |
|---|---|---|
| 3.1 | 6 | Suspension Effective Date (YY-MM-DD) |
| 3.2 | 2 | Suspension Type |
| 3.3 | 6 | Suspension Expiration Date (YY-MM-DD) |
| 3.4 | 1 | Code =1 if suspension cancelled on appeal |

**4. Collision Segment** (Space for 25 collisions at 1Ø characters per collision

| Field # | Width | Description |
|---|---|---|
| 4.1 | 6 | Collision Effective Date (YY-MM-DD) |
| 4.2 | 1 | Collision Nature (Severity) |
| 4.3 | 2 | Apparent Driver Action |
| 4.4 | 1 | Driver Condition |

Table 1: (ctd.)

**5. Cancellation Segment** (Space for 1Ø cancellations at 6 characters per cancellation

| Field # | Width | Description |
|---|---|---|
| 5.1 | 6 | Cancellation Effective Date (YY-MM-DD) |

**6. Medical Condition** (Space for 1Ø at 1 character each)

| Field # | Width | Description |
|---|---|---|
| 6.1 | 1 | Code 1 if code 43 (drug abuse) is flagged,<br>2 if code 6Ø (Alcoholism - no seizure) is flagged<br>3 if code 61 (Alcoholism - seizure) is flagged |

**7. Demerit Point History** (Space for Field 7.1 plus 15Ø adjustments -- 7.2 to 7.4 -- at 9 characters each)

| Field # | Width | Description |
|---|---|---|
| 7.1 | 4 | Total Demerits points at January 1, 1981. |
| 7.2 | 4 | Month and Year of Adjustment (YY-MM) |
| 7.3 | 4 | Change to Demerit Point Total |
| 7.4 | 1 | Code 1 for Reinstatement |

Of the 827,995 drivers, 311,691 had no convictions or accidents during 1981-1984. To save on storage space, these records were kept in a separate file. Of the 516,304 drivers who had at least one conviction and/or accident during 1981-1984, records for approximately 400,000 were stored in an on-line file. The layout of this file is shown in Table 2.

The processing of this amount of data can be costly. For some purposes, smaller data sets are sufficient. With this in mind, three sets of driver records were assembled: a full set of records, and smaller samples of every 40th record and every 400th record.

## 3.0 PREPARATION FOR ANALYSIS

Making sense of large data sets requires careful preparation. The several preparatory activities are described below.

### 3.1 Checks for Representativeness of the Sample

Several tests were conducted to check whether the characteristics of a smaller sample (1 in 40 records) were similar to known (published) characteristics of the Ontario driving population. In terms of percent of male and female drivers, percent of accidents involving males, and accident involvement per driver/year the sample data were found to be reasonably representative of the Ontario driving population (See Table 3).

### 3.2 Consistency Checks

Driver record data were then checked for consistency. A number of inconsistencies were noted. The first inconsistency apparent in the data was that while some offenses are logically associated with the occurrence of an accident, the count of such offenses exceeded the count of related accidents. Thus, for example, one would expect that if a driver were convicted of failing to remain at the scene of an accident, he or she would also show an accident associated with the offense on that same day. However, this is clearly not so; in the small sample there were 45 such convictions, but only 28 accidents for drivers convicted of this offense. There is a similar discrepancy for convictions for "following too close" which apparently arise mainly from accidents. These discrepancies suggest that many accidents related to convictions have not been entered in the driver record file. It is possible that this omission might apply to accidents in general. One reason for this may be due to the fact that records contain only reports of "reportable" accidents whereas charges apply to any.

A second inconsistency was the considerable year-to-year fluctuation in the number of convictions for certain offenses. For example, the number of convictions for driving without a permit increased from 0 in 1981 to 68 in 1984. There were seven other conviction types with similar inconsistencies from year-to-year. The reason for these inconsistencies is not clear, but they could be related to changes in enforcement practices or to modifications related to regulations.

**TABLE 2: Description of data in on-line master file**

| Field # | Width | Description |
|---|---|---|
| **Record 1**: Basic record (Fixed record length = 42) | | |
| 1A | 2 | Birth Year |
| 1B | 1 | Sex: Code 1 for male, 2 for female |
| 1C | 3 | License class(es) |
| 1D | 3 | Demerit Point Total at time of "dump" |
| 1E | 2 | Number of convictions, 1981-1984, n1 |
| 1F | 2 | Number of Accidents, 1981-1984, n2 |
| 1G | 2 | Number of demerit point adjustments, 1981-84, n3 |
| 1H | 8x3 | Suspension days unpaid fine, 1981 |
| | | " " other , 1981 |
| | | " " unpaid fine, 1982 |
| | | . . |
| | | . . . |
| | | Suspension days other , 1984 |
| 1I | 1 | Code 1 if any flags for drugs or alcohol |
| 1G | 2 | Demerit Point Total at January 1, 1981 |
| **Record 2**: Conviction Record (Variable - space for n1 convictions) | | |
| 2A | 1 | Year (1981=1, and so on) |
| 2B | 5 | Conviction Code |
| 2C | 3 | Speed Limit (for speeding convictions) |
| 2D | 3 | Recorded Speed for Speeding Conviction |
| 2E | 2 | Demerit Points assigned |
| 2F | 1 | Code 1 for non-accident related, single conviction |
| | | 2 for non-acc. related, primary of multiple conv. |
| | | 3 for non-acc. related, secondary of multiple " . |
| | | 4 for accident related, single conviction |
| | | 5 for accident related, primary of multiple conv. |
| | | 6 for " " , secondary of " " . |
| **Record 3**: Accident Record (Variable -- space for n2 accidents) | | |
| 3A | 1 | Year (1981=1, and so on) |
| 3B | 2 | Severity code |
| 3C | 3 | Apparent Driver Action Code |
| 3D | 1 | Driver Condition Code |
| **Record 4**: Record of demerit point adjustments (Variable record length -- space for n3 adjustments) | | |
| 4A | 2 | Month # from Jan. 1981, of adjustment |
| 4B | 1 | Sign of adjustment: + = points added |
| 4C | 2 | Demerit Point change |
| 4D | 1 | Code 1 if reinstatement after suspension |

**TABLE 3: Comparison of sample with population***

| Characteristic | Sample Value | Population value |
|---|---|---|
| % male drivers | 53.4% | 56% |
| % female drivers | 46.6% | 44% |
| % of accidents involving males | 72.2% | 72.9% |
| % of accidents involving females | 27.8% | 27.1% |
| Involvements per driver/year | Ø.Ø64 | Ø.Ø57 |
| Proportion fatal & injury involvements (all accidents) | Ø.35 | Ø.35 |

* - Population values are estimated from the Ontario MTO 1985 Annual Accident report and are for a comparable age distribution.

The third inconsistency involved the original licensing date. This variable was found to be unreliable. Some of the dates were missing and none of the the original dates were earlier than 1966 although a substantial number of drivers were obviously licensed before that year. This meant that the effect of experience on a driver's accident record could not be examined. This is a result of the development of the computer system in 1966 and of changes of residence and lapses of renewal that affect the recording of the original date.

## 3.3 Accident Related Convictions, Multiple Convictions and At-Fault Accidents

We anticipated that some models for the estimation of accident potential would make use of the driver's accident record. To avoid double-counting, convictions which were the consequence of accident involvement had to be identified. For the purpose of later analysis, we identified a conviction as being accident-related if it occurred on the same date as an accident. In a sample of 16,000 drivers we found 8940 convictions in two years. Of these, 612 (7%) were for violations which the driver incurred on the same day as an accident.

If several convictions were recorded on the same date, they were assumed to be related to a single apprehension. We think that only the "primary" conviction should feature in the statistical model; inclusion of secondary convictions could obscure the relationship between cause and effect.

Each offense type was assigned a rank, as shown in Table 4 according to how likely it was to be the cause of an apprehension. Thus, for example, speeding was given the highest rank. For multiple convictions, the one for the offense with the highest rank was called the primary conviction, while the others were designated as secondary convictions. In case of a tie, the first conviction recorded was designated as the primary one. This logic is somewhat arbitrary, but analysis of a data sample showed that only about 4% of all apprehensions result in multiple convictions. In addition, some 55% of the multiple convictions involved speeding - an obvious primary offense.

The information in Field 3C (See Table 2) - Apparent Driver Action - was used subsequently in the determination of whether or not an accident was "at-fault". All accidents with apparent driver action codes other than "driving properly", were considered at-fault accidents. These accidents included some 12% of involvements for which apparent driver action was either "not known" or "other". The decision to place these involvements in the "at-fault" category was made after discussions with police. Also, since "driving properly" already accounted for about 50% of involvements, it was logical to assume that the rest of the involvements were "at-fault".

## 3.4 Exploratory Analysis

The sample of every 40th record was used to perform some exploratory analyses. Figure 1 depicts the relationship between accidents and convictions in four years in a sample of nearly 16,000 drivers. It shows that drivers with more convictions tend to have more accidents. Thus, for example, the 189 drivers with 6 convictions in four years had, on the average, eight times as many accidents (line 1) as drivers with no convictions in these four years.

TABLE 4:

Multiple convictions (same day) in sample of 7811 drivers with ranking according to reason for apprehension:

1 = most likely; 4 = unlikely

**Rank 1**

| Offence | Code | No. in Sample |
|---|---|---|
| Dr. m/v, no valid plates | 10034 | 1 |
| No plate, operate m/v | 10063 | 3 |
| Imp./insuff./ drvg. lamps | 10420 | 9 |
| Imp. no. plate lamp | 10530 | 6 |
| Excess fumes/smoke | 10870 | 2 |
| Unnecess. noise | 10880 | 7 |
| Horn/bell violation | 10890 | 1 |
| Speeding -- km in --km zn. | 11355 | 211 |
| Careless driving | 11490 | 22 |
| Fail to stop, intersec. | 11580 | 25 |
| Fail to yield ROW at stop | 11590 | 2 |
| Fail yield ROW at yield | 11610 | 1 |
| Fail to yield ROW, Pr. rd. | 11620 | 2 |
| PXO viol. oth. side of rd. | 11650 | 1 |
| Pass at Ped. crossing | 11665 | 2 |
| Imp. RT at intersection | 11693 | 1 |
| Improper left turn | 11713 | 2 |
| Imp. LT at intersection | 11723 | 3 |
| Improper left turn | 11733 | 1 |
| " " from parked pos. | 11760 | 3 |
| Disobey red light | 11860 | 26 |
| " amber " | 11870 | 2 |
| Disob. green arrow | 11900 | 1 |
| Prohibited turn | 11920 | 10 |
| Disobey red light | 11925 | 2 |
| Fail to share road | 11940 | 3 |
| Imp. pass.- appr. traffic | 12010 | 2 |
| Driving left of center | 12040 | 2 |
| Pass on right/off r'way | 12100 | 1 |
| Wrong-way,one-way street | 12110 | 2 |
| Imp. driving, div. h'way | 12120 | 4 |
| Disobey off.signs,div.h'way | 12140 | 1 |
| Fail to stop for emer/veh. | 12200 | 1 |
| Imp. park., Interf. w.traf | 12430 | 1 |
| Prohibited turn | 80020 | 1 |
| By-law, proh. Turn | 80110 | 1 |

**Rank 2**

| Offence | Code | No. in Sample |
|---|---|---|
| Imp. rear lamp on trl. | 10570 | 1 |
| View obstr., sign/poster | 10800 | 1 |
| Rear window obstructed | 10850 | 1 |
| Def/imp/no muffler | 10860 | 4 |
| F.T.C., motor vehicle | 12180 | 4 |
| Fail to rep. accident | 12710 | 16 |
| Fail remain at scene accid. | 12730 | 10 |
| Fail rep. dam. to hy. prop. | 12760 | 2 |
| Dang. driving CCC | 70060 | 1 |
| Fail rem at accid. CCC | 70090 | 6 |
| Danger. driving CCC | 70120 | 2 |
| Impaired driving C.C.C. | 70174 | 23 |
| Fail/ref. breath test CCC | 70185 | 1 |
| Fail or ref. breath sam.CCC | 70212 | 19 |
| Driving with >80 mgs.alcoh. | 70214 | 15 |

**Rank 3**

| Offence | Code | No. in Sample |
|---|---|---|
| Imp. signal devices | 10610 | 1 |
| No safe helmet, motor cy. | 11090 | 3 |
| Fail/imp. use of Seat Belt | 11097 | 85 |
| Insecure load | 11260 | 2 |
| Excess veh. width | 11310 | 1 |
| Excess len. veh-comb. | 11320 | 1 |
| Excess veh. height | 11350 | 1 |
| Crowding driver seat | 12240 | 1 |

**Rank 4**

| Offence | Code | No. in Sample |
|---|---|---|
| Dr. m/v,no valid permit | 10033 | 19 |
| No valid. tag on plates | 10035 | 7 |
| Draw trailer, no permit | 10037 | 3 |
| fail surr. m/v permit | 10038 | 7 |
| " " trl. " | 10039 | 1 |
| fail not. ch. address | 10050 | 3 |
| Fail apply for permit | 10071 | 2 |
| Imp. plates on veh. | 10130 | 3 |
| No driver's license | 10190 | 39 |
| Driv., cond. proh. | 10193 | 2 |
| Fail to prod. dr. license | 10210 | 45 |
| No lic., fail to ID self | 10214 | 1 |
| Pos. canc/susp. license | 10222 | 2 |
| Unlaw. pos. license | 10320 | 1 |
| Dr. lic. susp. H.T.A. | 10332 | 31 |
| Def. brakes, contr. to reg. | 10680 | 1 |
| Def./imp tires | 10750 | 2 |
| Refuse exam. unsafe veh. | 10980 | 1 |
| Fail to carry/prod.permit | 13210 | 3 |
| More than 1 license | 13270 | 1 |
| No insurance | 20010 | 2 |
| Op. m/v, no insurance | 20011 | 5 |
| False statem. re. insurance | 20030 | 1 |
| Fail to have insurance card | 20050 | 20 |
| " " carry " " | 20060 | 2 |
| " " " evid. of ins. | 20070 | 1 |
| Dealer plate infraction | 90250 | 1 |
| Learner unaccompanied | 90700 | 1 |
| " " fail not. addr. ch. | 90810 | 6 |

# 4 YRS CONVICTIONS VS 4 YRS ACCIDENTS

15935 DRIVERS, '81–'84

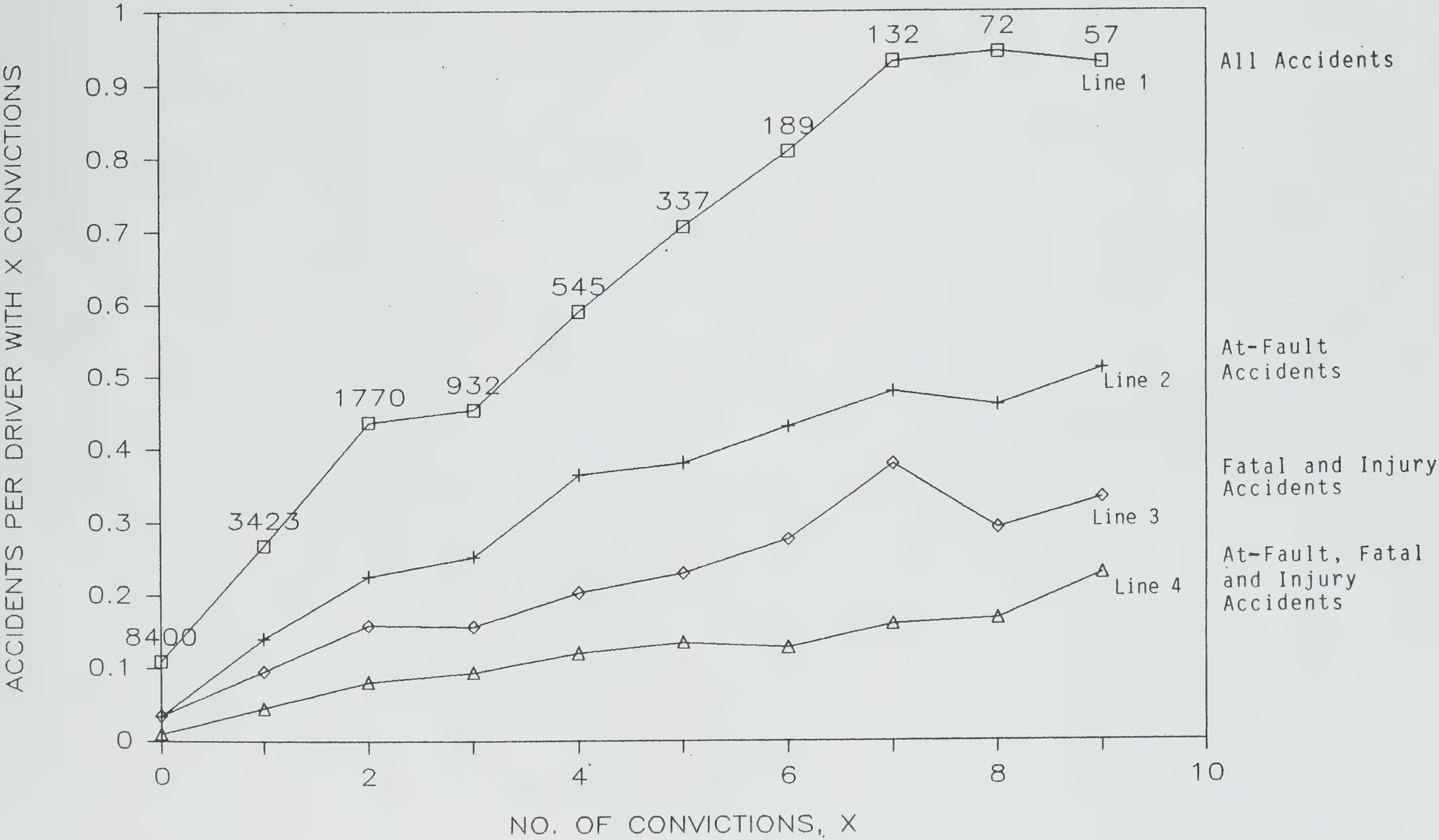



Figure 1

(Convictions which were incurred on the date of an accident were eliminated from consideration). The same pattern prevails for at-fault accidents (line 2), fatal and injury accidents (line 3) and at-fault, fatal and injury accidents (line 4). Figure 2 shows similar results. However, this time the relationship between convictions in the first two year period and the average number of accidents in the subsequent two-year period is plotted.

These two figures leave no doubt that convictions and accidents are correlated. However, correlation should not be taken to indicate causality. It is, in fact, very likely that the number of accidents in which a driver is involved and the number of convictions which a driver incurs are both related to the distance driven. Thus, the observed statistical correlation reflects a hidden common link, exposure, about which we have no information.

It deserves noting that about 2/3 of all drivers have no convictions in a two-year period. We are interested mainly in the accident potential of drivers who have convictions. In addition, the difficulties of computing are greatly reduced if only that 1/3 who had one or more convictions are used for data. It is for these reasons that the core of the analysis described in Section 4 used the records of drivers who in the first two years had one or more convictions.

### 3.5 Selection of Conviction Categories

A preliminary analysis of a sample of about 8000 drivers indicated that, over the four-year period 1981-1984, these drivers were convicted for approximately 200 different traffic offenses. Speeding accounted for some 60% of non-accident related convictions; seat-belt offenses accounted for about 10%, and failure to stop at an intersection for about 5%. Most of the other offense types had very few convictions. It was obviously impractical to estimate how much these "leaner" convictions added to a driver's accident potential. It was therefore necessary to aggregate offenses with few convictions into larger groups. (It should be noted that the same approach is already present in the current demerit point-system. There are essentially 8 categories of offenses, that is, those assigned 0,1,2,3,4,5,6 and 7 demerit points. For example, all the non-moving violations as well as some of the moving ones fall into the 0 point category.)

#### Determining Conviction Categories: Step 1

The clustering of all possible offense types into a manageable number of groups was accomplished in several steps. The first step was to combine the offense types which are quite similar in nature into a smaller number of categories. A total of 45 such categories were established in our discussions with MTO in April 1987. These consisted of 38 categories of moving violations, 3 for vehicle-related offenses, and 4 for non-moving, administrative violations. (See Table 5.)

This first round of clustering was based on judgment of similarity. In the second round, groups of offenses were identified which were similar in their contribution to the average number of accidents of a driver. To obtain results which are unambiguous and free of confounding, the only records used

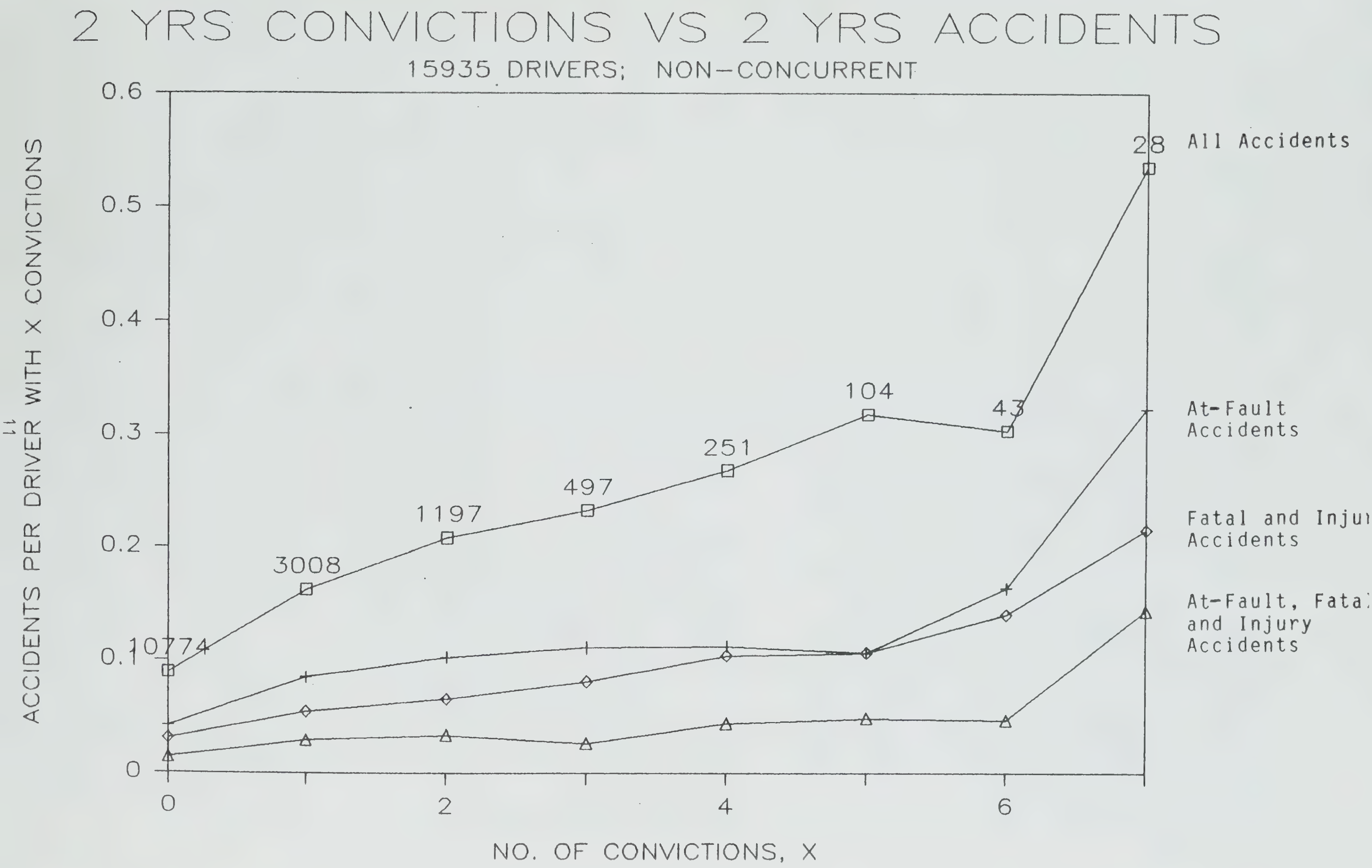

2 YRS CONVICTIONS VS 2 YRS ACCIDENTS
15935 DRIVERS; NON-CONCURRENT
ACCIDENTS PER DRIVER WITH X CONVICTIONS
0.6
0.5
0.4
0.3
0.2
0.1
0
10774
3008
1197
497
251
104
43
28
All Accidents
At-Fault Accidents
Fatal and Inju
Accidents
At-Fault, Fata
and Injury
Accidents
0
2
4
6
NO. OF CONVICTIONS, X

Figure 2

TABLE 5: Accidents for Drivers with 1 Conviction in 1 Year

| Category | Brief Description | No. of Drivers | 3 yr. Accs. | Weighted Mean | 95% Limits Upper | Lower |
|---|---|---|---|---|---|---|
| n1 | Minor neglect, licenses, permits | 6495 | 2918 | 0.434 | 0.445 | 0.422 |
| n2 | Neglect, insurance, permits, etc. | 1589 | 719 | 0.414 | 0.438 | 0.392 |
| n3 | License suspended, HTA | 874 | 454 | 0.424 | 0.456 | 0.394 |
| n4 | Learners | 34 | 18 | 0.343 | 0.502 | 0.212 |
| v1 | Minor veh.; lamps, noise | 2954 | 1498 | 0.468 | 0.485 | 0.451 |
| v2 | Brakes, tires, unsafe vehicle | 946 | 451 | 0.400 | 0.430 | 0.371 |
| v3 | Comm.veh; size & weights | 503 | 369 | 0.542 | 0.583 | 0.500 |
| m1 | Seat belt | 12337 | 4858 | 0.376 | 0.384 | 0.368 |
| m2 | Speeding | 173592 | 55211 | 0.319 | 0.321 | 0.317 |
| m3 | Careless driving | 902 | 342 | 0.327 | 0.357 | 0.299 |
| m4 | Slow driving | 45 | 11 | 0.119 | 0.237 | 0.055 |
| m8 | STOP sign, ROW violations | 14024 | 3935 | 0.288 | 0.295 | 0.281 |
| m9 | PXO violations | 1237 | 355 | 0.296 | 0.320 | 0.272 |
| m10 | Turns violations; right, left, U | 18231 | 4942 | 0.283 | 0.289 | 0.277 |
| m11 | Unsafe move; open door | 1649 | 542 | 0.334 | 0.355 | 0.312 |
| m13 | Disobey red light | 13731 | 4270 | 0.313 | 0.321 | 0.306 |
| m14 | Amber light | 3453 | 982 | 0.285 | 0.299 | 0.271 |
| m15 | Advance green | 274 | 73 | 0.265 | 0.317 | 0.218 |
| m16 | Fail to share road | 170 | 62 | 0.303 | 0.372 | 0.242 |
| m17 | Passing violations | 1305 | 459 | 0.327 | 0.351 | 0.303 |
| m18 | Wrong-way one way street | 1582 | 458 | 0.284 | 0.306 | 0.264 |
| m19 | Improper driving divided h'way | 2599 | 900 | 0.361 | 0.379 | 0.344 |
| m20 | F.T.C. | 934 | 337 | 0.344 | 0.374 | 0.316 |
| m21 | Emerg. veh., school x'ing | 48 | 15 | 0.159 | 0.280 | 0.084 |
| m22 | R/R crossing violations | 95 | 35 | 0.314 | 0.408 | 0.233 |
| m24 | Headlight beam not lowered | 225 | 71 | 0.260 | 0.318 | 0.209 |
| m25 | Improper parking | 145 | 77 | 0.407 | 0.484 | 0.334 |
| m26 | Fail stop for school bus | 604 | 133 | 0.281 | 0.317 | 0.249 |
| m28 | Disobey traffic signs | 1650 | 529 | 0.322 | 0.344 | 0.301 |
| m29 | Fail report accident | 224 | 73 | 0.266 | 0.324 | 0.215 |
| m30 | Fail remain at scene | 236 | 75 | 0.315 | 0.373 | 0.261 |
| m32 | Dangerous driving C.C.C. | 5 | 2 | 0.010 | 0.421 | 0.000 |
| m33 | Fail remain at accident C.C.C. | 66 | 39 | 0.377 | 0.491 | 0.274 |
| m34 | Dangerous driving C.C.C. | 89 | 46 | 0.281 | 0.376 | 0.202 |
| m35 | Impaired driving C.C.C. | 2381 | 1040 | 0.443 | 0.462 | 0.424 |
| m36 | Fail/refuse breath test C.C.C. | 94 | 37 | 0.218 | 0.306 | 0.149 |
| m37 | Fail or ref. breath test C.C.C. | 120 | 50 | 0.314 | 0.397 | 0.241 |
| m38 | Driving with >80 mgs. alcohol | 3676 | 1502 | 0.386 | 0.401 | 0.371 |
| m41 | Crowding driver seat | 120 | 36 | 0.280 | 0.362 | 0.211 |
| m44 | Radar device in vehicle | 68 | 27 | 0.251 | 0.359 | 0.166 |
| m45 | No safe helmet, motorcycle | 96 | 47 | 0.266 | 0.357 | 0.191 |
| m46 | Fail to signal to stop | 18 | 6 | 0.080 | 0.277 | 0.019 |
| m47 | FTC, commercial vehicle | 67 | 35 | 0.362 | 0.475 | 0.262 |
| m48 | Fail to stop for police officer | 12 | 6 | 0.086 | 0.340 | 0.016 |

were those for drivers who in any one of the four years had a single conviction. The results given in Table 5 are based on the entire sample. Thus, for example, there were 12337 drivers who in one year were convicted for not wearing a seat belt (offense m1) and had no other convictions in that year. During the remaining three years these drivers recorded 4858 accidents for an average of 0.394 accidents per driver. To eliminate any bias due to differences in the age-gender distribution which might be associated with specific offenses, all averages were recalculated for a "standard population" (for more detail, see Appendix 1). The "standard population" used had an age-gender composition which was characteristic of those drivers who had exactly one conviction of any kind in one of the four years. This is why in the "Weighted Mean" column the average number of accidents in the remaining three years associated with this seat belt offense is listed as 0.376. Similarly, the 173,592 drivers who had only a single speeding conviction (m2) in some year have an adjusted average of 0.319 accidents in three years. The last two columns give 95% confidence limit for the weighted mean.

<u>Categorization of Speeding Offenses</u>: The current point allocation system establishes four levels of severity according to how much the speed limit is exceeded. However, exceeding the speed limit by 20 km/h, whether in a 40 km/h or a 100 km/h speed zone, carries the same number of demerit points. Since there were many speeding convictions in the data base, the question of how the average number of accidents depends on the speed limit and on the extent to which the speed limit is exceeded was examined.

Figures 3 and 4 show the frequency of violations for various speeds over the limit. It seems clear that there is a tendency for "speeds over limit" to be rounded to multiples of 5 km/h. However, the largest numbers of violations are for 14 km/h over the speed limit. Since demerit points are given for 15 km/h or more over the speed limit, it appears that either drivers consciously drive just below this number or, more likely, that there is some mitigation by police officers for speeds just beyond 14 km/h over the speed limit (perhaps to account for inaccuracies in radar gun and speedometer readings). A similar situation exists, though less pronounced, for 29 km/h over the limit, just below the 30 km/h at which demerit points are increased from 3 to 6.

As a result of the anomaly noted above, dividing speeding convictions for the purpose of determining the relative seriousness of various "speeds over limit" can produce misleading results. In a division based, say, on the current system, most convictions in the 0-14 km/h over the limit category should really belong to the seemingly more serious 15-20 km/h over limit category. Similarly, the 15-29 km/h category may contain many convictions that belong in the 30 km/h or more over the limit category. Thus regression weights for each category might wrongly indicate that the 3 categories are similar in terms of seriousness.

We have examined in detail whether drivers who have in some year exactly one speeding conviction of given gravity differ in their average number of accidents during the remaining three years. The results are given in Table 6. It turns out that there is no systematic or practically significant difference between the average number of accidents either by speed limit zone or by the amount by which the speed limit is exceeded, or by the combination of both criteria.

FIGURE 3

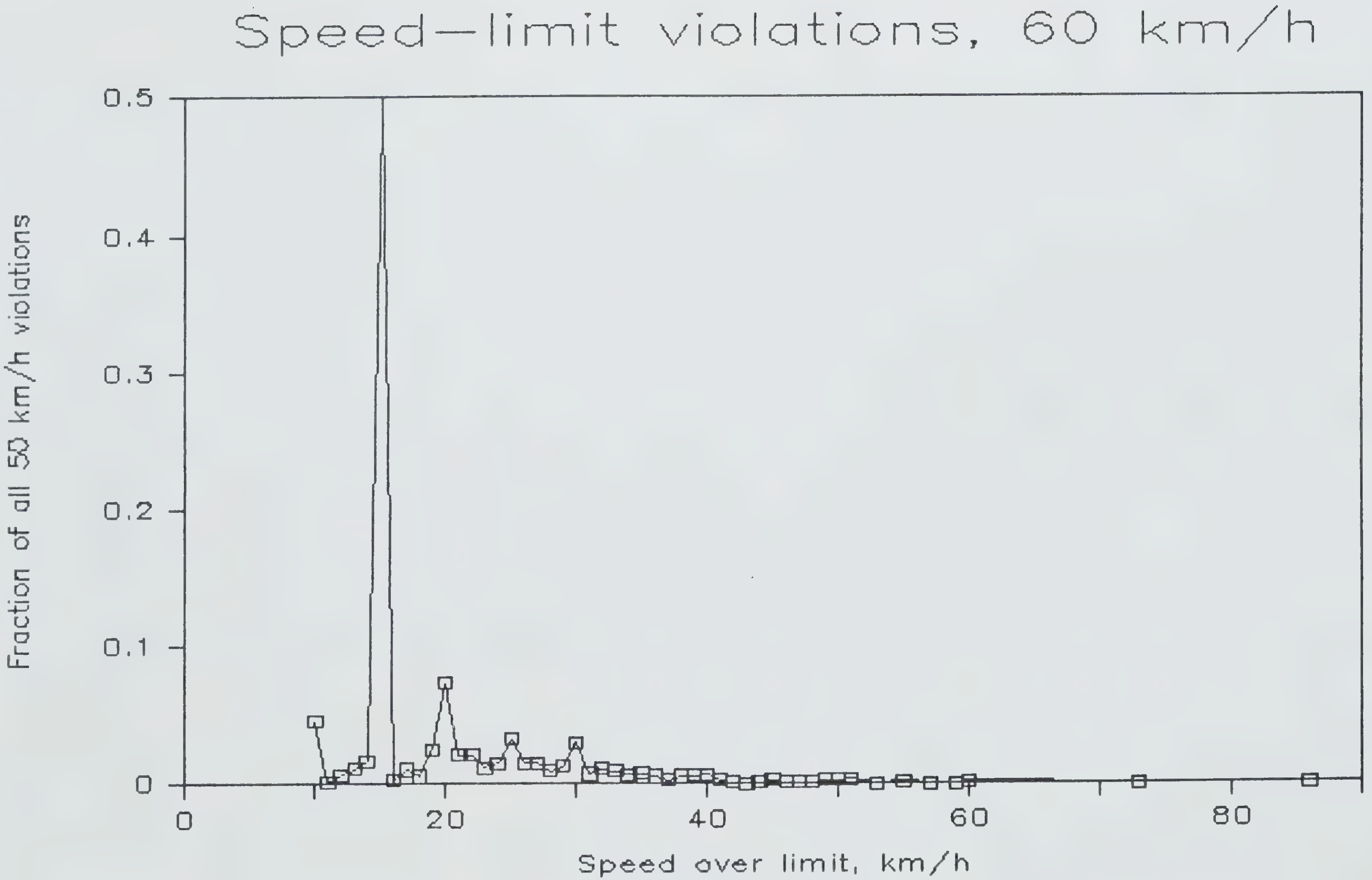
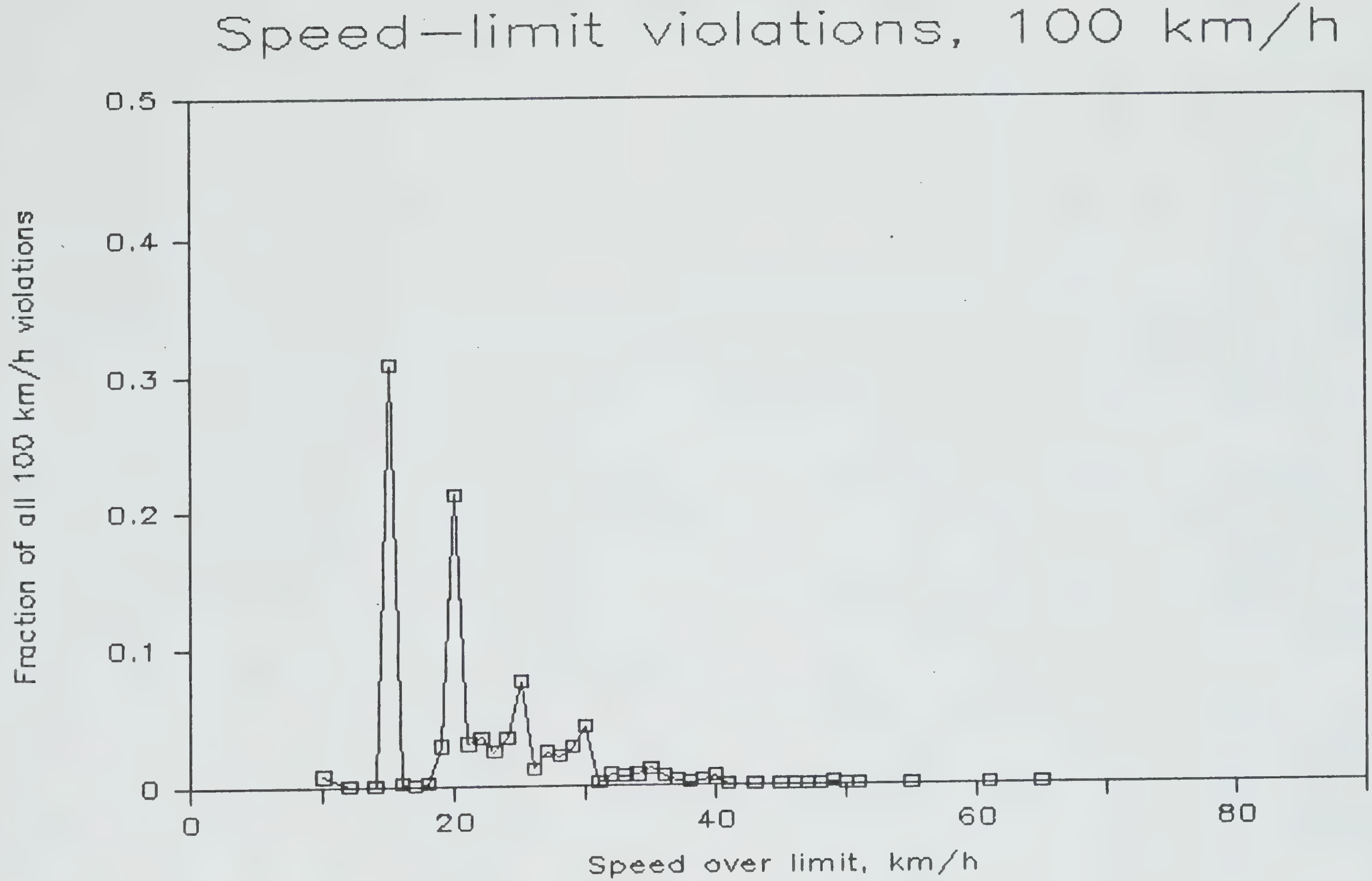

Speed—limit violations, 60 km/h
Fraction of all 50 km/h violations
0.5
0.4
0.3
0.2
0.1
0
0
20
40
60
80
Speed over limit, km/h

FIGURE 4



Speed—limit violations, 100 km/h
Fraction of all 100 km/h violations
0.5
0.4
0.3
0.2
0.1
0
0
20
40
60
80
Speed over limit, km/h

TABLE 6 : Accidents for drivers with 1 speeding conviction in 1 year

| Speed Limit | Above Limit | No. of Drivers | 3 yr. Accs. | Weighted Mean | 95% Limits Upper | Lower |
|---|---|---|---|---|---|---|
| All | 0-15 | 123224 | 33755 | 0.293 | 0.296 | 0.291 |
| All | 16-29 | 79589 | 22479 | 0.286 | 0.289 | 0.283 |
| All | 30-49 | 23891 | 7331 | 0.297 | 0.302 | 0.291 |
| All | >49 | 894 | 371 | 0.315 | 0.344 | 0.286 |
| 20-40 | 0-15 | 24264 | 6307 | 0.288 | 0.293 | 0.283 |
| 50-70 | 0-15 | 80248 | 22037 | 0.294 | 0.297 | 0.291 |
| 80-100 | 0-15 | 18712 | 5411 | 0.292 | 0.298 | 0.286 |
| 20-40 | 16-29 | 5276 | 1413 | 0.281 | 0.293 | 0.270 |
| 50-70 | 16-29 | 39995 | 11427 | 0.293 | 0.297 | 0.288 |
| 80-100 | 16-29 | 34318 | 9639 | 0.281 | 0.285 | 0.276 |
| 20-40 | 30-49 | 683 | 185 | 0.269 | 0.302 | 0.239 |
| 50-70 | 30-49 | 9304 | 2914 | 0.305 | 0.314 | 0.296 |
| 80-100 | 30-49 | 13904 | 4232 | 0.292 | 0.300 | 0.285 |
| 20-40 | >49 | 14 | 8 | 0.186 | 0.432 | 0.064 |
| 50-70 | >49 | 405 | 183 | 0.341 | 0.386 | 0.299 |
| 80-100 | >49 | 475 | 180 | 0.272 | 0.312 | 0.236 |

Determining Conviction Categories:Step 2 On the basis of such comparisons, it was possible to combine some of the 45 conviction categories which were found to be associated with similar average numbers of accidents. The resulting 14 conviction groupings, the associated three-year average number of accidents and 95% confidence limits of the estimate are shown in Table 7 and plotted in Figure 5. Also shown are estimates of accident potential for conviction-free drivers, those who had no convictions of any type during one calendar year.

In summary, the final 14 conviction categories to be used in analysis were established on the basis of the following considerations:

1. Conviction types within each category were similar in nature;

2. The accident potential associated with each conviction within a category was similar in size;

3. The number of drivers having offenses in each category was considered sufficient to provide a reliable estimate of accident potential for that category.

A list showing which convictions are included in the first 14 conviction categories is given in Appendix 2.

### 3.6 Discussion of Conviction Categories

Inspection of Figure 5 leads to the question of why it is that convictions for some of the innocuous offenses (e.g. for a burnt-out light bulb, nn1) are found to be associated with more accidents than offenses traditionally deemed very dangerous such as speeding (mm7) or running a red light (mm2). Several reasons combine to explain this apparent paradox. First, convictions associated with most accidents are those characteristic of trucks. Since trucks cover 10-20 times the distance of a passenger car per year, it is to be expected that they will have, on the average, more accidents. The second reason is easier to explain through an example. Assume that 1000 run-the-red offenses lead to 5 accidents and that 1000 fail-to-signal-turn offenses lead to 1 accident. Thus, we are assuming that to run-the-red is a more dangerous offense than failing to indicate a turn. However, the enforcement of both offenses is unequal (perhaps because one is assumed to be more dangerous than the other). Assume further that of the 1000 run-the-red offenses, 10 lead to a conviction whereas of the 1000 fail-to-signal offenses 1 leads to a conviction. Thus, a figure similar to Figure 5 would show 5/10 = 0.5 accidents per conviction for running the red and 1/1 = 1.0 accident per conviction for failure to indicate a turn. Even though, according to our starting assumption, running the red is five times more dangerous than failing to indicate a turn, because enforcement of the two offenses is unequal, the final results show the contrary. The problem is caused by the fact that the driver record contains information about the number of convictions, not the number of of illegal actions committed by a driver for which he is not convicted. This is the data with which we have to work. A third reason may be related to the connection between different types of behaviour and convictions. The incidents on a person's driving record, convictions and accidents, may be indications of their overall driving behaviour. As a result

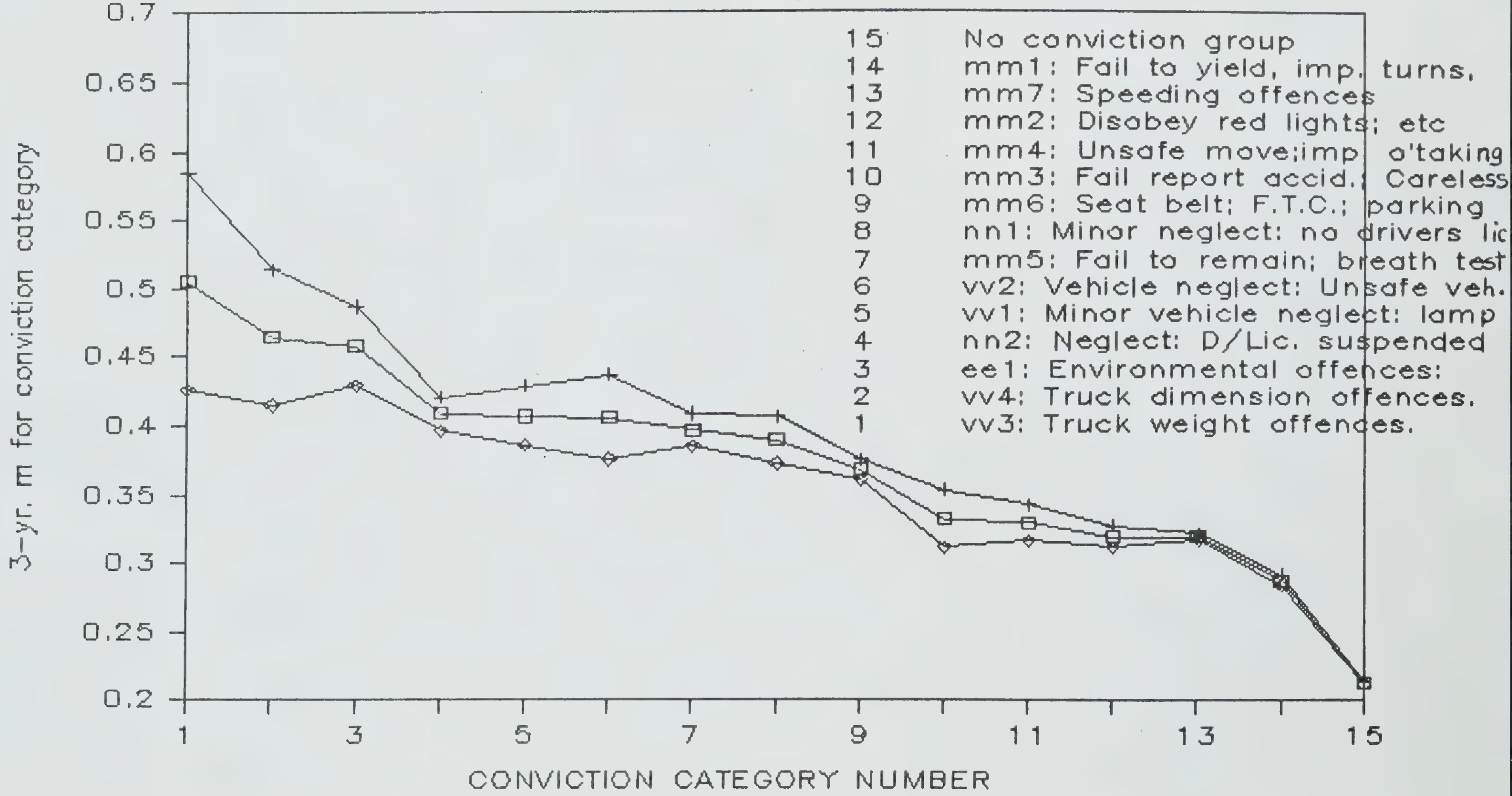
TABLE 7 : 3-YEAR MEAN ACCIDENTS FOR DRIVERS WITH 1 CONVICTION IN 1 YEAR. (Based on Final Conviction Categories)

| Category (Final) | Brief Description | Drivers | Accidents | 3-Year Mean | 90% Limits Upper | Lower |
|---|---|---|---|---|---|---|
| mm1 | Fail to yield, improp.turns,etc | 37775 | 10425 | 0.287 | 0.291 | 0.282 |
| mm2 | Disobey red lights etc. | 13183 | 4169 | 0.319 | 0.326 | 0.311 |
| mm3 | Fail report acc; C'less driving | 1774 | 657 | 0.332 | 0.353 | 0.311 |
| mm4 | Unsafe move, overtaking | 4606 | 1514 | 0.329 | 0.342 | 0.316 |
| mm5 | Fail to remain; breath test | 6263 | 2563 | 0.396 | 0.408 | 0.385 |
| mm6 | Seat belt; FTC; parking | 15454 | 5885 | 0.367 | 0.375 | 0.360 |
| mm7 | Speeding | 165852 | 52623 | 0.318 | 0.321 | 0.316 |
| nn1 | Minor neglect;plates,license | 2865 | 1166 | 0.388 | 0.405 | 0.372 |
| nn2 | Neglect;d/lic. suspended | 5720 | 2485 | 0.408 | 0.420 | 0.396 |
| vv1 | Minor vehicle: lamps, etc. | 1802 | 786 | 0.406 | 0.428 | 0.385 |
| vv2 | Vehicle: tires, brakes, unsafe | 903 | 441 | 0.405 | 0.436 | 0.375 |
| vv3 | Insecure load | 134 | 94 | 0.505 | 0.584 | 0.425 |
| vv4 | Weight & dimension offences | 348 | 214 | 0.464 | 0.513 | 0.415 |
| ee1 | Environmental offences | 1022 | 527 | 0.457 | 0.486 | 0.428 |
| | Drivers with no convictions | 2047414 | 337745 | 0.216 | 0.213 | 0.212 |

F I G U R E 5

3 yr. m's for drivers with 1 conviction

Final conviction groupings



the types of convictions committed by certain types of people may also provide insight into their potential for accidents. If a person engages in certain behaviours which lead to certain convictions they may also engage in certain other behaviours which predispose them to accidents. To illustrate with an example, drivers with environmental types of convictions (e.g. noisy muffler) were found to have a higher weighted mean of accidents than drivers with most other types of convictions. Most drivers quickly have their noisy muffler fixed and are unlikely to receive this type of conviction. The attitude which results in drivers coming to the attention of the police and being charged with this offense may be related to a similar careless attitude towards behaviour which results in accidents.

All of the three reasons discussed above affect the correlation between a particular offense category and accidents. Thus, correlation does not necessarily indicate causality. Two conclusions follow. First, one should not interpret the results in Figure 5 as providing information about the danger inherent in this or that offense. Second, one should not be surprised when, later, in section 4, the same innocuous offenses will prove to be strongly related to the driver's estimated accident potential.

### 3.7 Age and Gender Categories

It is well known that the average number of accidents for a driver depends on gender and age. To account for this fact, age and gender will be used in the analysis as "variables". It is relatively simple to account for gender since it comes in two natural categories. However, the relationship between age and number of accidents is continuous in nature and distinctly non-linear as is shown in Figure 6. To include age in the analysis it was necessary to establish a number of age categories. After careful analysis, the boundaries between age groups were chosen so that the average numbers of accidents within each group remained nearly constant while still keeping sufficient numbers of drivers within each age category to maintain statistical reliability. The following eight age categories were chosen:

<21
21-25
26-30
31-35
36-40
41-50
51-60
>60

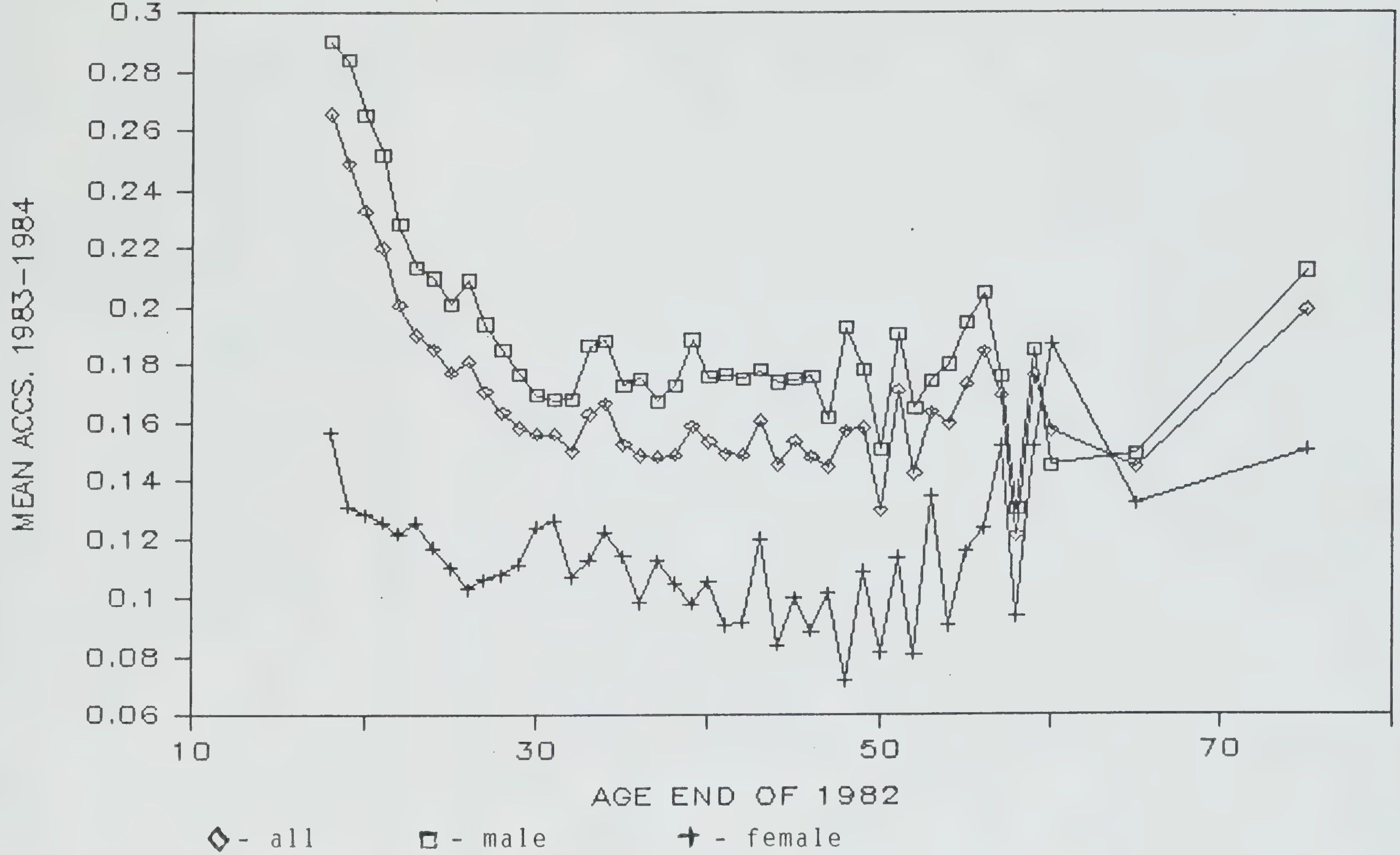
### 3.8 Exclusion of Drivers with Suspended Licenses

Some drivers in the sample had their license suspended during the study period. Most of these are drivers who had many convictions which carried demerit points. The extent to which a suspended driver curtails his or her driving is unknown. This leads to serious difficulty in the statistical analysis. Consider a driver who in the first two-year period had many convictions and was suspended. That driver can be expected to drive less in the second two-year period and therefore to have proportionately fewer accidents.

FIGURE 6

## PER.2 ACCS. BY AGE AND SEX

DRIVERS WITH >0 CONS., 1981–1984



In the statistical analysis this would tend to create a negative correlation between accidents and convictions. That is, it would lead to the incorrect result that the larger the number of convictions in the first two years, the fewer accidents a person is likely to have in a subsequent period. The net effect of this difficulty is to distort the results of analysis in some unpredictable way. In fact, in the initial statistical analyses, this distortion was so large that negative weights were produced for criminal code offenses for which drivers were likely to be suspended. (The implication of a negative weight is the paradoxical result that the offense is associated with fewer subsequent accidents.) As a result of this finding, it was necessary to remove from the data set and from subsequent analysis those drivers whose license had been suspended during any time in the period 1981-1984. The result of this decision is that whatever results are obtained in the course of the analysis apply directly only to those drivers whose licenses have not been suspended. The extension to drivers who were suspended under the present demerit point system is therefore an extrapolation.

## 4.0 ANALYSIS AND RESULTS

The various activities described so far (checking representativeness, conducting consistency checks, the exploratory analysis of data, the selection of conviction categories, determination of age groups and the removal of suspended drivers) are all preliminary to the main activity, namely the establishment of a relationship between information contained in a driver's record and his or her expected number of future accidents. The information used was a driver's gender, age, the count of accidents (at-fault, not-at-fault or total), and the count of convictions in each of the fourteen categories. This information from the first two years was used to estimate "weights" which best fitted the accident record in the second two-year period. Weights which are associated with each conviction category can be taken to be relative numbers of "points" which should be assigned for the best prediction of the likelihood of an accident in the second two-year period. Only records of those drivers who had at least one conviction in the first two-year period were used (n ~170,000).

### 4.1 Schemes and Variants Examined

The MTO was interested in a number of variants, each using different sets of variables. These fall into three categories:

1) models which made use of age and gender information and models which did not;

2) models which assigned points for period 1 accidents (with the further distinction between at-fault, not-at-fault and total), and models which did not assign points for accidents; and

3) models which assigned different numbers of points for each conviction category and models in which all convictions carried the same weight.

In total 16 different combinations of variables from the first two-year period were used. For each of these, "weights" were estimated. Each of these 16 combinations results in a prediction equation which is termed a "model".

Table 8 shows which variables were used in each "model". Thus, for example, model B2 calculates the expected number of period-two accidents using the count of period-one convictions in each of the 14 types (see Table 7) as well as the count of total period-one accidents; model C4 uses driver age and gender, the count of all convictions (without distinction with respect to type), the count of at-fault accidents and the count of not-at-fault accidents.

Half of the models tested (A1-A4, B1-B4) allowed for a different weight to be given to each of 14 conviction types. The other 8 models tested used a weighting of 1 point per conviction, that is, all 14 conviction types were considered equivalent (models C1-C4, D1-D4). Half of the models used age and gender as variables, to aid in the prediction of accidents in the second two year period (models A1-A4, C1-C4).

One quarter of the models (A1, B1, C1 and D1) used only information on convictions in the first two year period to predict accidents in the second two year period. One quarter of the models (A2, B2, C2 and D2) used total accidents in the first two year period as well as convictions, to predict subsequent accidents. One quarter (A3, B3, C3 and D3) used only at-fault accidents and convictions for prediction purposes. Finally, one quarter (A4, B4, C4 and D4) used separate weights for at-fault and not-at-fault accidents, as well as convictions (also separately weighted: A4, B4 or one point per conviction: C4, D4) to predict subsequent accidents.

## 4.2 What is a "Model" and how does it "Work"

By "model" we mean a mathematical equation which allows the estimation of a driver's expected number of accidents in "period two" on the basis of that driver's age, gender, record of convictions and record of accidents in "period one". Like many others, we have elected to use the linear-sum form.

To illustrate, consider a female driver, 24 years of age who in the first period had two speeding convictions, one conviction for failing to yield the right of way (ROW), and one at-fault accident. To estimate her expected number of period two accidents we consider the importance of each variable.

| Variable | Weight | Count | Contribution |
|---|---|---|---|
| Base Driver | 0.176 | - | +0.176 |
| For being female | -0.061 | - | -0.061 |
| For being 24 yrs. | -0.039 | - | -0.039 |
| For speedg. conv. | 0.027 | x2 | +0.054 |
| For ROW convic. | 0.027 | x1 | +0.027 |
| For accident | 0.058 | x1 | +0.058 |
| Estimate of expected number of period two accidents | | | =0.215 |

TABLE 8 : VARIABLES USED FOR REGRESSION RUNS
(x -- indicates variable used in run)

| Run | Age and Sex dummy variables | Variables for each Conviction Group | Variable for total Convictions | Accident variables | | |
|---|---|---|---|---|---|---|
| | | | | Total | Fault | At Fault |
| A1 | x | x | | | | |
| A2 | x | x | | x | | |
| A3 | x | x | | | x | |
| A4 | x | x | | | x | x |
| B1 | | x | | | | |
| B2 | | x | | x | | |
| B3 | | x | | | x | |
| B4 | | x | | | x | x |
| C1 | x | | x | | | |
| C2 | x | | x | x | | |
| C3 | x | | x | | x | |
| C4 | x | | x | | x | x |
| D1 | | | x | | | |
| D2 | | | x | x | | |
| D3 | | | x | | x | |
| D4 | | | x | | x | x |

The "weights" in this illustrative example are for Model A2. (See Table 9.) Thus, we estimate that females who were 24 during 1981 and had during that period of time the aforementioned record of convictions and accidents, should be expected to have 0.215 accidents during 1983-1984 on average.

## 4.3 On the Estimation of "Weights" and "Diversity"

The main statistical work is the estimation of "weights". These were estimated for each model separately. For example, the weights for model A2 are given in the "Estimated Coefficient Column" of Table 9. The magnitude and relative importance of the weights for model A2 is shown in Figure 7. A full collection of such tables for all 16 models is provided in Appendix 3. In Appendix 4 we give fuller technical details about the distinctive features of the estimation procedure and the software used.

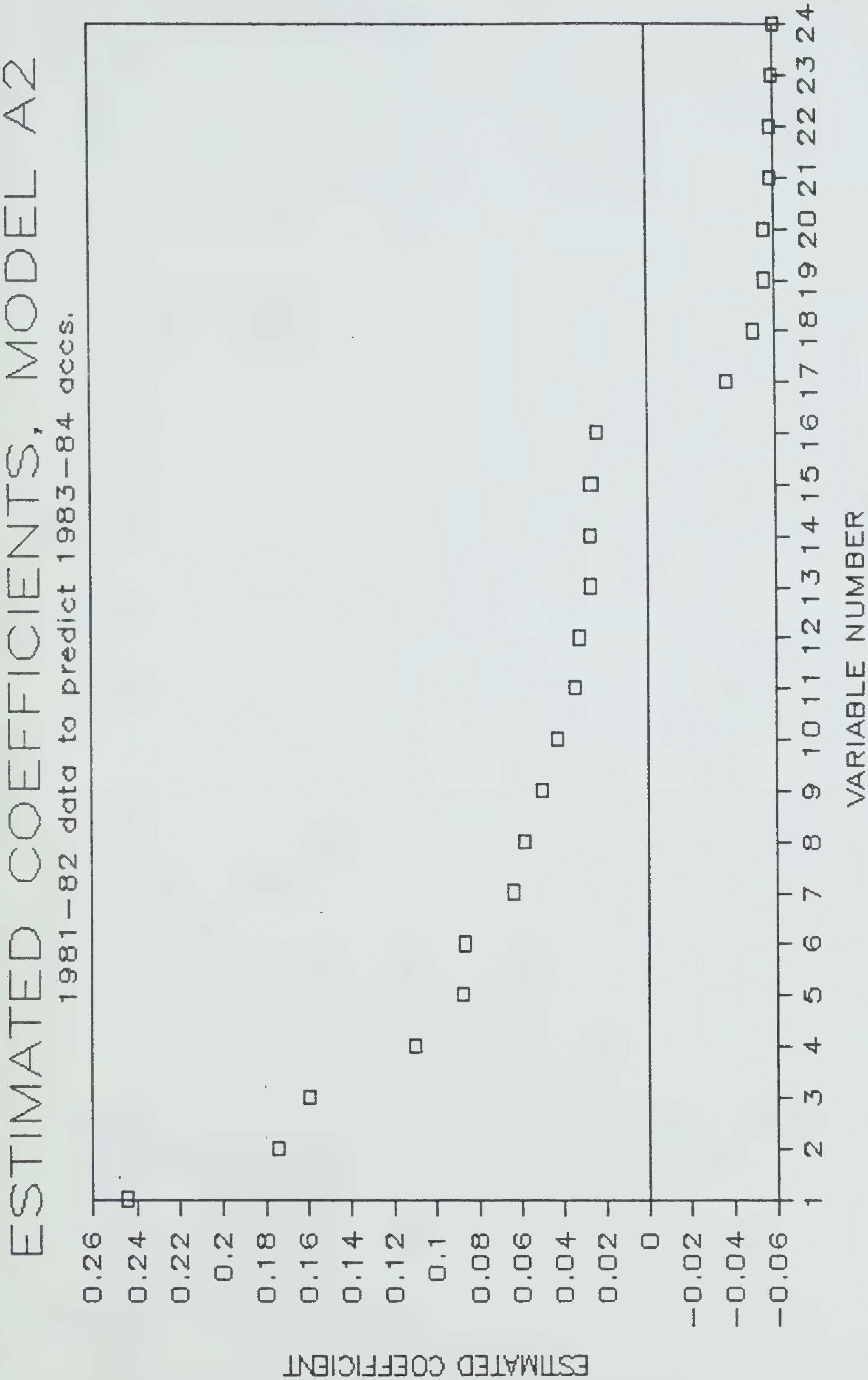
The model weights allow us to estimate the expected number of accidents of an average driver with known age, gender and record of convictions and accidents. However, while this is true for an "average" person fitting such traits, any specific driver in this group will have her own "expected number of accidents". Our statistical procedure also allows us to describe the diversity within each group. Having obtained estimates of the "weights" for a model we have examined the data again in order to establish the standard deviation of what we estimate to be the expected number of accidents for a driver with given traits and record. It turns out that the estimate of standard deviation is equal to the estimate of expected number of accidents multiplied by a constant. The list of "constants" for the 16 models is given below.

| Model | Constant |
|---|---|
| A1 | 0.67 |
| A2 | 0.64 |
| A3 | 0.66 |
| A4 | 0.64 |
| B1 | 0.71 |
| B2 | 0.68 |
| B3 | 0.69 |
| B4 | 0.68 |
| C1 | 0.67 |
| C2 | 0.65 |
| C3 | 0.67 |
| C4 | 0.65 |
| D1 | 0.72 |
| D2 | 0.69 |
| D3 | 0.71 |
| D4 | 0.68 |

TABLE 9: Regression coefficients for Model A2

| Description of variable | Estimated Coefficient | Standard Error |
|---|---|---|
| Intercept (Male, Age < 21) | 0.1763 | 0.002876 |
| Dummy variable for age 21-25 | -0.03856 | 0.002852 |
| Dummy variable for age 26-30 | -0.0565 | 0.002913 |
| Dummy variable for age 31-35 | -0.06006 | 0.003044 |
| Dummy variable for age 36-40 | -0.05202 | 0.003516 |
| Dummy variable for age 41-50 | -0.06013 | 0.00351 |
| Dummy variable for age 51-60 | -0.05774 | 0.004832 |
| Dummy variable for age > 60 | -0.06156 | 0.007068 |
| Dummy variable for female | -0.06122 | 0.001735 |
| mm1: Fail to yield, imp. turns, PXO, amber violations, etc | 0.02696 | 0.001753 |
| mm2: Disobey red lights; rail crossing violations. | 0.042125 | 0.002916 |
| mm3: Fail report accid.; Careless driving; Dang. driving;Crim. neg. caus. death | 0.023304 | 0.008613 |
| mm4: Unsafe move;imp. o'taking; Disobey signs | 0.06359 | 0.004959 |
| mm5: Fail to remain; breath test; alcohol; impairment. | 0.2444 | 0.054575 |
| mm6: Seat belt; F.T.C.; parking; divided h'way offences. | 0.03221 | 0.00213 |
| nn1: Minor neglect: no drivers license; permits; insurance, address change | 0.02624 | 0.010463 |
| nn2: Neglect: D/Lic. suspended or not produced; plates, insurance. | 0.03366 | 0.003708 |
| vv1: Minor vehicle neglect: lamps windows obstructed, etc. | 0.04954 | 0.006561 |
| vv2: Vehicle neglect: Unsafe veh., brakes, tires | 0.08673 | 0.009296 |
| vv3: Insecure load | 0.159215 | 0.02721 |
| vv4: Weights and dimension offences | 0.11074 | 0.011895 |
| ee1: Environmental offences: noise, fumes. | 0.08748 | 0.008334 |
| mm7: Speeding offences | 0.026515 | 0.000866 |
| Total accidents in period 1 | 0.05831 | 0.001580 |

FIGURE 7


ESTIMATED COEFFICIENTS, MODEL A2
1981–82 data to predict 1983–84 accs.
ESTIMATED COEFFICIENT
VARIABLE NUMBER
0.26
0.24
0.22
0.2
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
−0.02
−0.04
−0.06
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24

Thus, for example, the standard deviation of "expected number of accidents" for females of the aforementioned group is estimated to be 0.215x0.64 = 0.138. The "constants" above are an index of model performance. The larger the constant, the larger the standard deviation, and the less accurately we know the accident potential of a certain driver. The ability to describe the diversity of "accident potential" within specific groups of drivers will prove important when we analyze the performance of the current demerit point scheme and compare it to the performance of other "models".

## 4.4 The Accident Potential of Ontario Drivers

The models estimate, for each driver, the "number of accidents he or she is expected to have per year". This is not an integer because its nature is that of a "long-term-average". For brevity this number is called a driver's accident potential. Of course, not all drivers have the same accident potential; some drive more, some drive less, some take risks, others are more cautious. Prior to examining the results for each model, let us examine the diversity of accident potential in the population of Ontario drivers. This will reveal how many drivers there are in the population who have a high accident potential. How many of these "high accident potential" drivers will indeed be identified for post-licensing-control under the current demerit point system and the new weighting models, will be examined later.

The number of accidents in the second two-year period was used to compute the mean accident potential (0.055 accidents/year) and standard deviation of accident potential (0.055 accidents/year) in the total driver record sample. Details of the method are given in Appendix 4.3. This information was then used to plot the distribution of accident potential in a population of 5 million Ontario drivers shown in Figure 8.

Using Figure 8 one can estimate how many drivers in the population are at each level of accident potential. Thus, for example, it can be seen that about 1.75 million drivers, or 1/3 of the drivers, have an accident potential which is higher than the average. (It is less than 1/2 of the population because there are some drivers with a very high accident potential). Let us now find out how many drivers have an accident potential which is much higher than the mean for this population. Consider drivers whose accident potential is 3 standard deviations above the mean or higher, that is, an accident potential larger than 0.22 accidents/year. From Figure 8 it can be seen that almost 90,000 drivers have an accident potential of 0.22 or higher.

It is drivers with a high accident potential who are to be identified for post-licensing-control. However, it must be noted that a driver may have a high accident potential because of bad driving as well as because of high exposure to risk. If a driver is likely to have x accidents driving y kilometers, the same driver is likely to have 2x accidents driving 2y kilometers. Thus, it is very important to ascertain whether one has identified, through the demerit point system, a driver who drives little but has a high accident potential or one who drives a lot and has a correspondingly high accident potential. The two drivers may require different treatments. For brevity we will denote accident potential by "m".

Numbers of drivers with
expected acidents/year
> value on X-axis

(Millions)

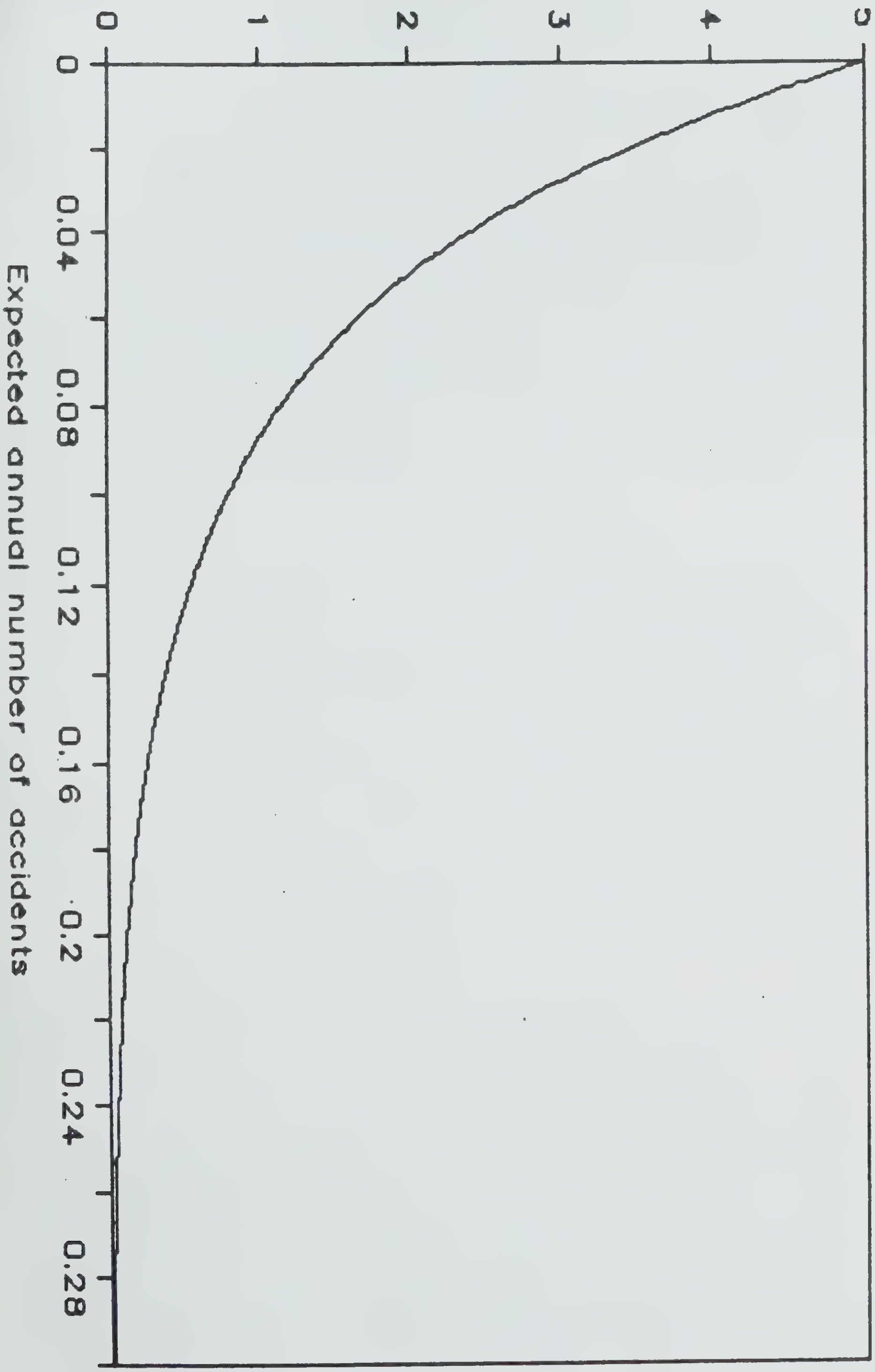



Figure 8: Distribution of accident potential in the Ontario Driving Population mean = 0.055 (±0.055) accidents/year

Ordinarily one is interested in the identification of drivers with unusually high m's. Figures 9-11 are successive enlargements of the right-hand tail of the curve in Figure 8. The reader must keep in mind the fact that the shape of the curve reflects the assumption that the distribution of m's is Gamma. We cannot be sure that this assumption is valid until we show that we can reproduce the actual accident data by using it. For example, if accidents were distributed in a bimodal fashion because people drove either a little or a great deal, and had either very few or a lot of accidents, then our assumption of a Gamma distribution would be incorrect and we would not be able to reproduce what is observed in terms of accident distribution by using the assumption. However, if accident data is distributed in a unimodal fashion then our experience is that the gamma distribution is a good approximation.

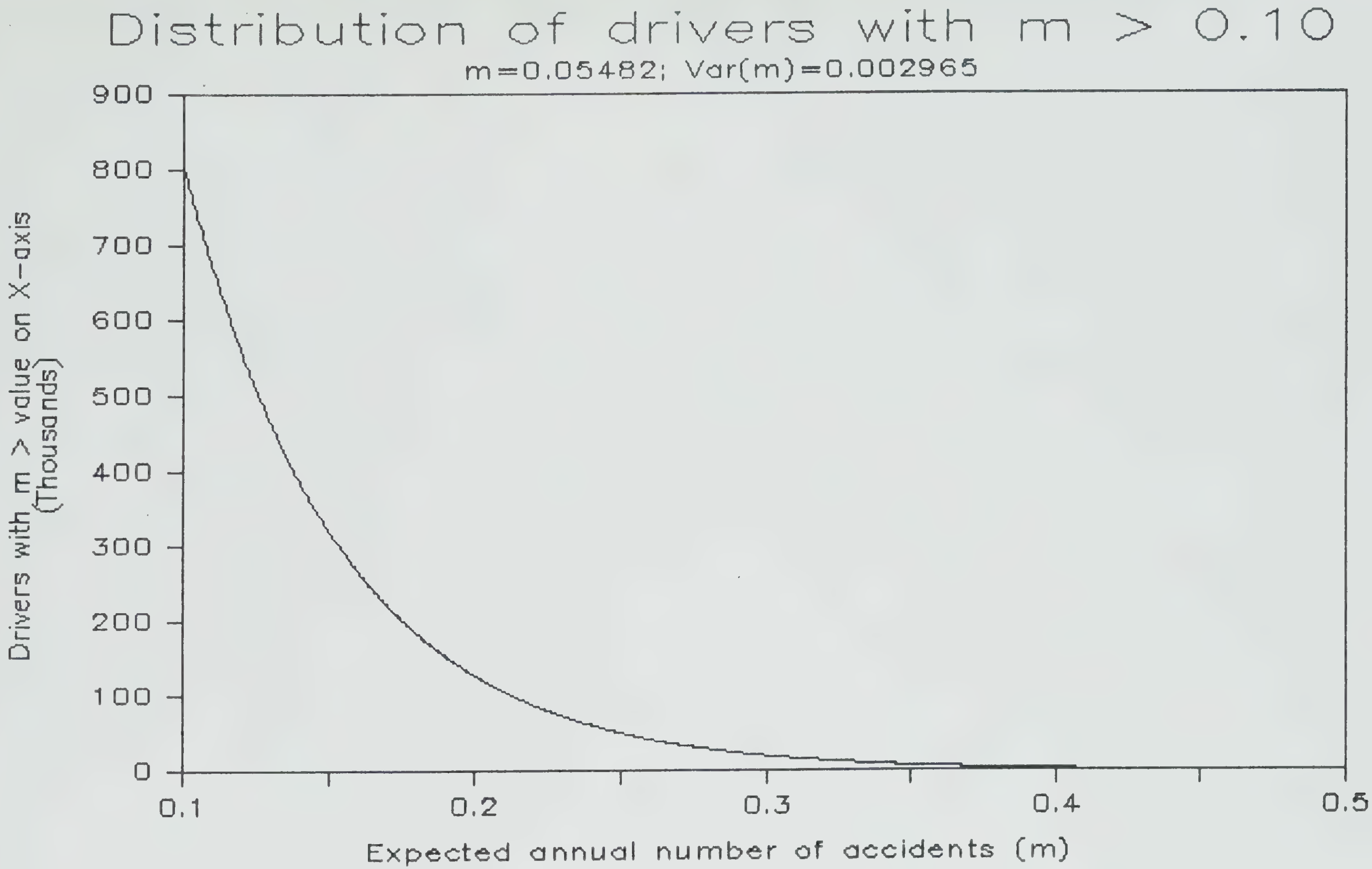
In Appendix 4 (Tables A4.1 through A4.25), we show the results of the check on the validity of our assumption of a Gamma distribution. For example males aged 21-25 years (Table 4.12) have a mean number of accidents in period one of 0.2049, and a variance of 0.2231. Using the Gamma distribution, with this mean and variance results in predictions which closely match what has been observed. Thus, for example, for drivers with 0 accidents in period one, we predict that there will be 45249.8 drivers who have 0 accidents in period two. The observed number of such drivers was 45054. The similarity between observation and prediction is consistent for the various age and sex groups This indicates that the Gamma assumption is reasonable.

The information contained in Figures 8-11 enables one to form an idea about the number of drivers with unusually high m's in the population. The problem is, of course, that these drivers are difficult to identify on the basis of their conviction and accident record. A driver may have a relatively low m while accumulating a large number of convictions and even accidents in a certain period of time. Conversely, a person who, in a very long period of time, would be recognized as having an unusually high m, might in a one or two year period have no accidents and no convictions. The models obtained in Section 4 can be thought of as a net; their purpose is to fish out those drivers who have an unusually large m. However, even the best models formulated in Section 4 are but an imperfect net for the identification of high-m drivers. Many such drivers will slip through its holes; many of those identified will not be high-m drivers. The degree of success and failure of the net will be examined next.

### 4.5 The performance of the current demerit point system and of the new models

Since the 16 new models were derived using appropriate statistical methods, rather than weighting each offense according to its perceived seriousness, they should perform better than the current demerit point system. However, all models face the same inherent difficulties as the current demerit point system. Namely, because of the randomness inherent in the process of accident occurrence and the randomness inherent in the process by which drivers acquire convictions, a two year record is just too short to accurately estimate a driver's accident potential. As will be seen, the new models are an improvement on the current system, but like the current system, still fail to detect most of the high accident potential drivers.

FIGURE 9


Distribution of drivers with m > 0.10
m=0.05482; Var(m)=0.002965
Drivers with m > value on X-axis
(Thousands)
900
800
700
600
500
400
300
200
100
0
0.1
0.2
0.3
0.4
0.5
Expected annual number of accidents (m)

F I G U R E 1 0

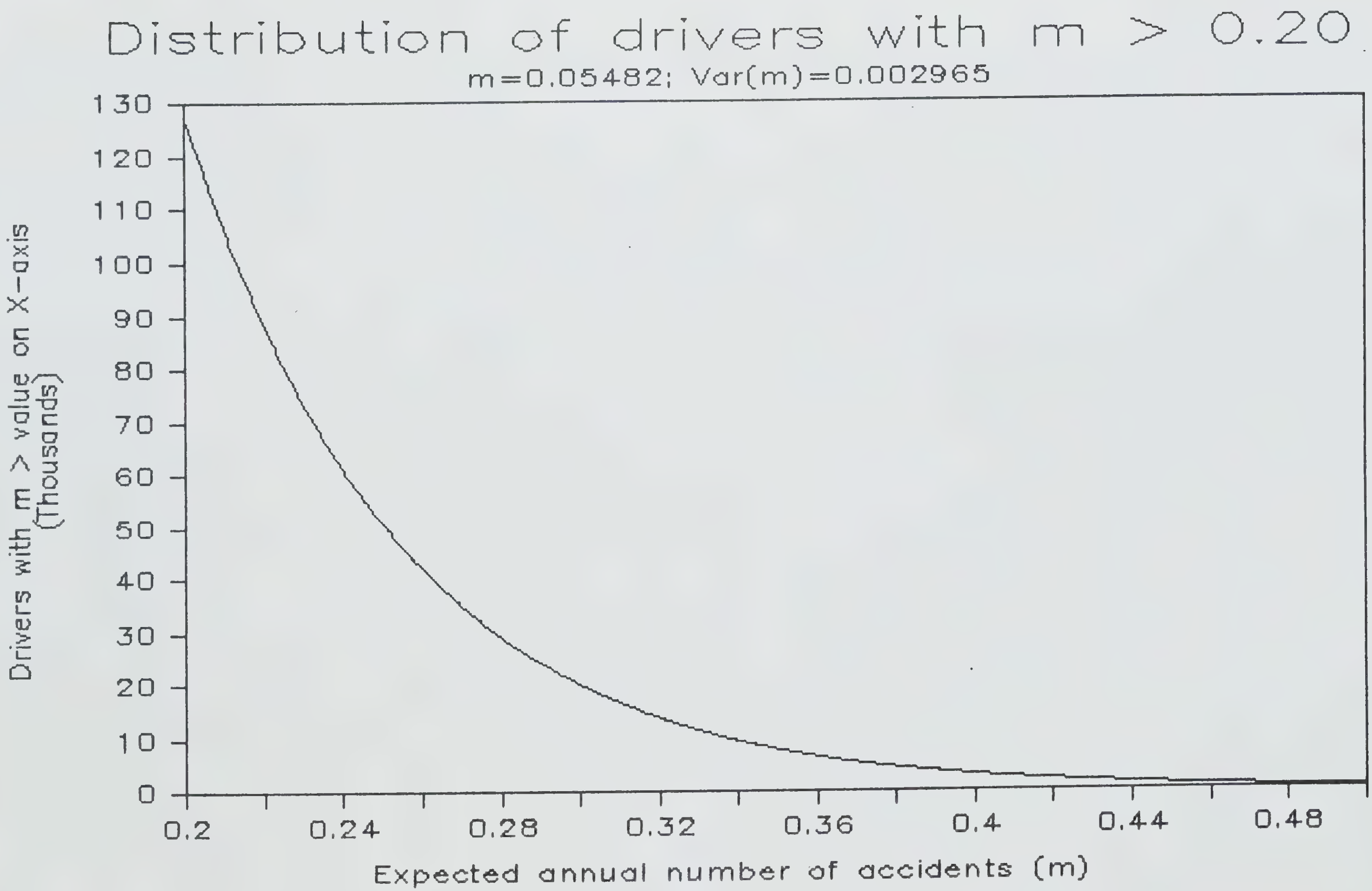
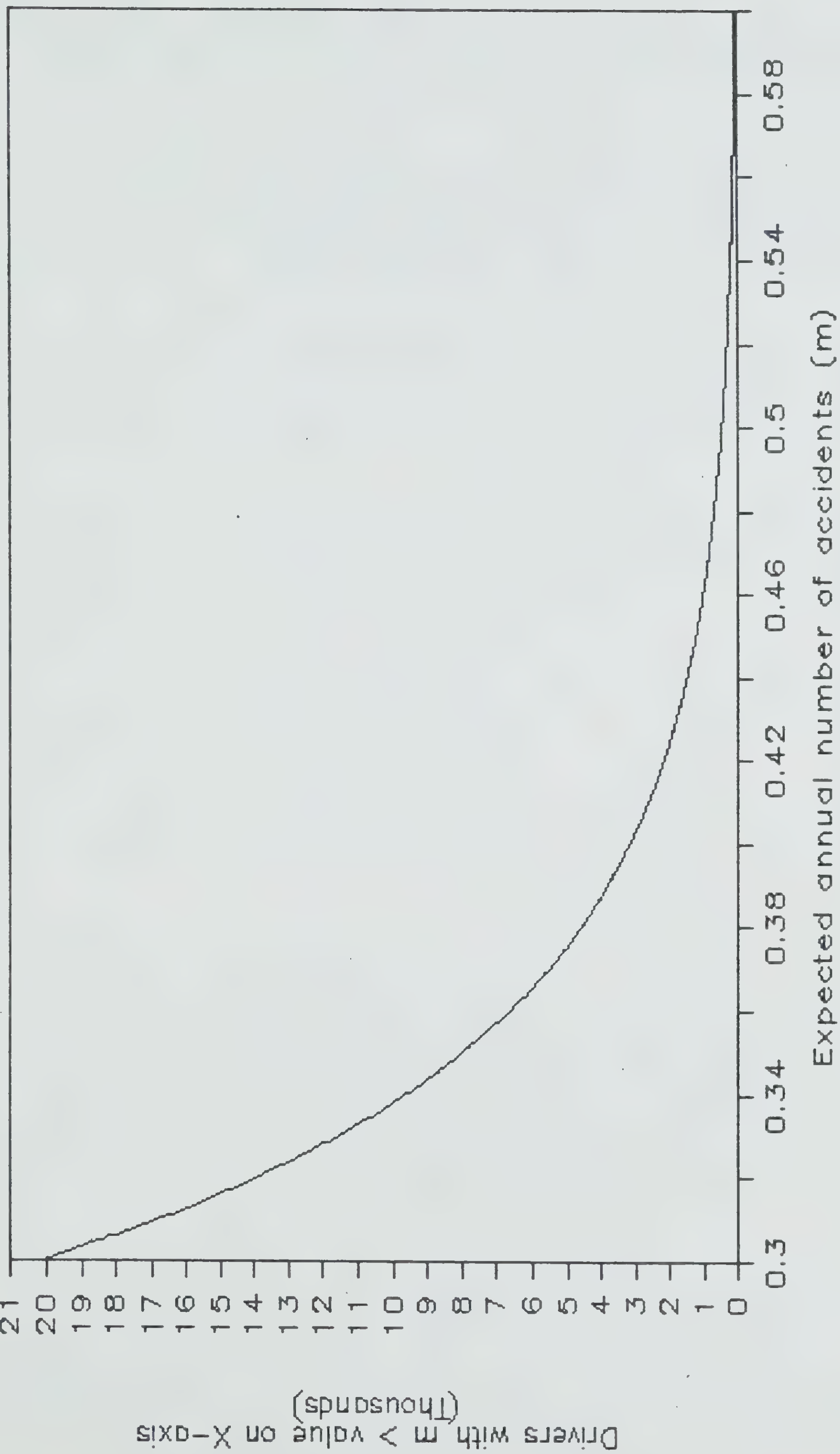

Distribution of drivers with m > 0.20
m=0.05482; Var(m)=0.002965
130
120
110
100
90
80
70
60
50
40
30
20
10
0
Drivers with m > value on X-axis
(Thousands)
0.2
0.24
0.28
0.32
0.36
0.4
0.44
0.48
Expected annual number of accidents (m)

FIGURE 11

Distribution of drivers with m > 0.30

m=0.05482; Var(m)=0.002965



Two measures of performance will be used to judge the quality of a model. The first is the number of period two accidents which have occurred to 10,000 drivers selected as worst by a model. The model which identifies drivers with most period two accidents will be judged the best.

The second measure of performance gives more detailed information. It tells us how many of the drivers estimated to have a high accident potential on the basis of their period one record are truly high accident potential drivers. These are the "hits". We also learn how many of these drivers have a true accident potential which is lower than the population average. These are the "false alarms".

The first measure of performance is straightforward. Consider, for example, the 10,000 drivers who in the first two year period had most demerit points. Checking the accident records of the same drivers, we find that during the second two year period they had 1452 accidents per year (see sum of entries in last row of Table 10).

Consider now another group of 10,000; this time those who who in the first two year period had the most accidents. For this second group we find that they recorded in the subsequent two year period 1828 accidents per year (1828 is the sum of the first three entries for accidents, that is, 312 in the first 1000, 756 in the next 4000, and 760 in the next 5000). Evidently, it is better to identify drivers by their previous accident record than by previous demerit points. Imagine now that a third group of 10,000 drivers is identified, this time those for whom model A4 estimates the highest accident potential on the basis of their age, gender, as well as convictions and accidents in the first two year period. This group has 2084 accidents per year in the second period. Thus, selection by model A4 gives a richer catch than either selection by previous accidents or by the current demerit points. In interpreting these results one has to keep in mind that the count of accidents is always subject to random fluctuations.

Several conclusions emerge. First, one can do better than to use the current demerit point weights. Second, it is important to make use of the driver's record of accidents. This is already evident from the comparisons of the last two rows. However, it also emerges from the poor performance of models A1, B1, C1 and D1 which do not make use of accident data. In fact, the top 1000 drivers can be well identified by their previous accident record alone. Third, the more drivers that are identified, the lesser the "yield". Thus, the top 1000 drivers have an accident rate of ~0.3 accidents/year which is approximately 6 times the population average; for the first 10,000 drivers the average accident rate is ~0.2 and so on.

The first measure of performance, examined above, leaves the impression that the drivers which are identified indeed have an accident potential which is substantially larger than that for the population of all drivers. While this is true for the group "on the average", this group itself may not be a homogenous one. The second measure of performance by which the quality of the alternative models is to be judged relates to the diversity of accident potential within the group of drivers which these models identify.

Table 10

| ACCIDENTS PER YEAR RECORDED BY DRIVERS SELECTED BY VARIOUS MODELS | | | | | | |
|---|---|---|---|---|---|---|
| Model | Drivers estimated by model to be in | | | | | |
| | Top 1,000 | Next 4,000 | Next 5,000 | Next 10,000 | Next 100,000 | Total |
| A1 | 188 | 712 | 904 | 1660 | 13308 | 16772 |
| A2 | 324 | 856 | 936 | 1798 | 14192 | 18016 |
| A3 | 276 | 736 | 860 | 1712 | 13700 | 17284 |
| A4 | 320 | 868 | 896 | 1736 | 14060 | 17880 |
| B1 | 212 | 704 | 824 | 1548 | 12888 | 16176 |
| B2 | 320 | 832 | 980 | 1628 | 13688 | 17448 |
| B3 | 272 | 748 | 804 | 1712 | 13336 | 16872 |
| B4 | 304 | 876 | 956 | 1636 | 13684 | 17456 |
| C1 | 208 | 744 | 760 | 1592 | 13016 | 16320 |
| C2 | 356 | 808 | 900 | 1672 | 13732 | 17468 |
| C3 | 276 | 780 | 780 | 1424 | 13684 | 16944 |
| C4 | 356 | 804 | 928 | 1616 | 13748 | 17452 |
| D1 | 176 | 748 | 688 | 1432 | 12260 | 15304 |
| D2 | 352 | 824 | 784 | 1608 | 13268 | 16836 |
| D3 | 244 | 756 | 852 | 1360 | 13084 | 16296 |
| D4 | 364 | 840 | 788 | 1576 | 13216 | 16784 |
| Accs.* | 312 | 756 | 760 | 1432 | 10780 | 14040 |
| DP** | 180 | 640 | 632 | Not | Available | |

* - Drivers with the highest accident counts in period 1 were selected

** - Drivers with the highest demerit points acquired in period 1

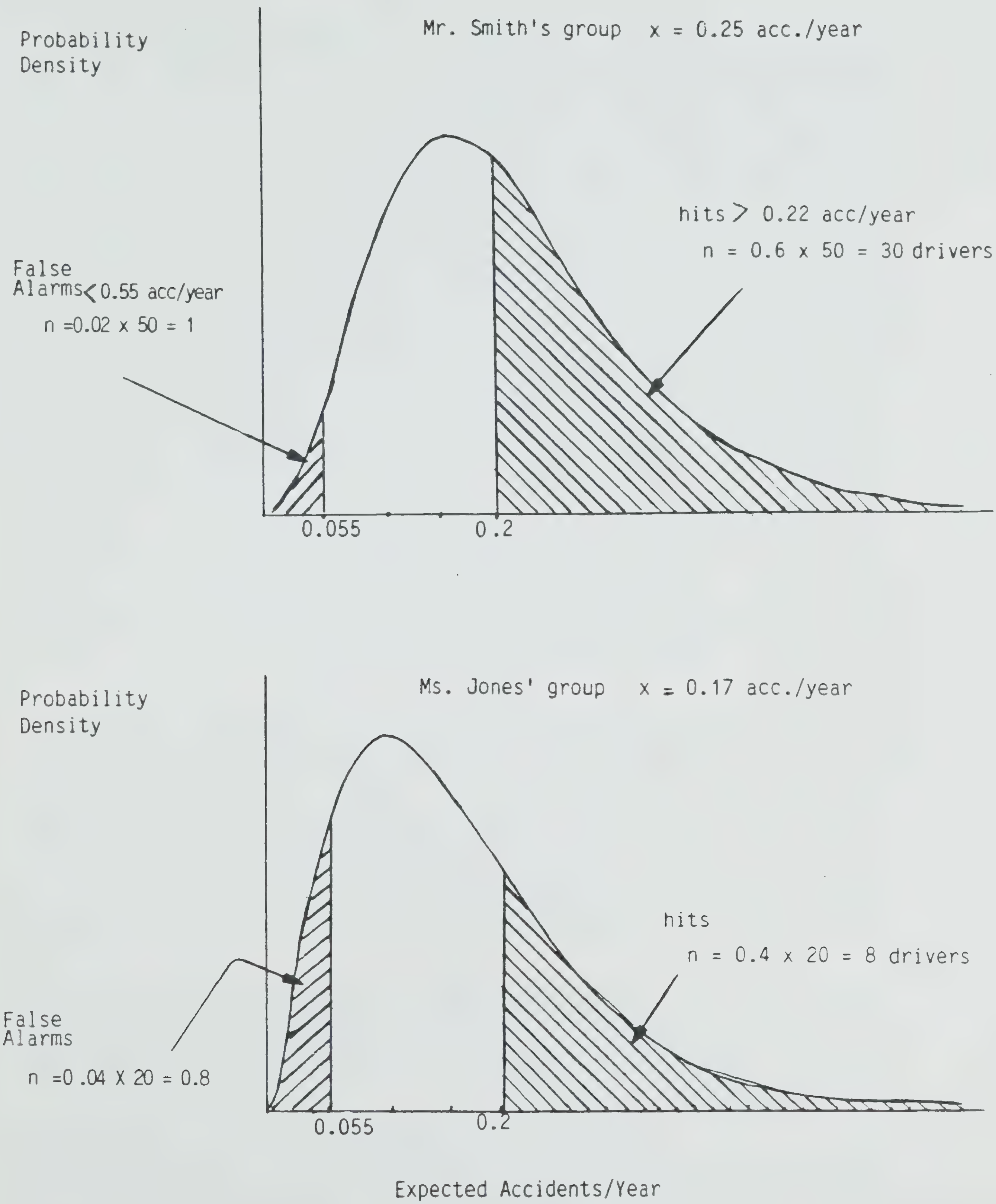
Second Performance Measure: Identifying Hits and False Alarms: A weighting scheme is like a net with which we attempt to catch drivers who, based on their two year record, are likely to have an unusually high number of accidents in the next two years. For the illustration here, consider "unusually high" to be 3 standard deviations above the mean. That is, we are hoping to identify drivers whose accident potential is larger than 0.22 accidents per year. If we manage to identify such a driver we will call this a "hit". Conversely, if based on the two year record we identify, and call in for treatment, a driver whose accident potential is lower than what is the average accident potential in the population, that is 0.05 accidents per year, we will call this a "false alarm".

Determining the hits and false alarms for each weighting scheme, or model, is a lengthy and rather complex procedure. It is not simply a matter of counting how many drivers had accidents in the second two year period, and how many did not. An explanation of the process, in general terms, follows. Let us consider one driver, out of a sample of 827,995, Mr. Smith. Mr. Smith's record of convictions and accidents in the first two year period is used to estimate his expected number of accidents per year in a subsequent time period, using one of the point schemes or models that have been developed, for example, A4. (See section 4.2 for details about the estimation of expected numbers of accidents using a driver's record and model A2). This process is then repeated for all other drivers. Now let us select those 1000 drivers who are estimated (say, using model A4), to have the highest expected number of accidents. (In the current demerit point system this is equivalent to selecting the 1000 drivers who have the highest number of demerit points). Let us suppose that Mr. Smith is among these.

Among the 1000 drivers there will be other drivers of the same age group, sex, and record as Mr. Smith. These drivers, though similar to Mr. Smith in these three characteristics, will drive different amounts, in different driving styles and are expected to have different numbers of accidents. For example, some who are in fact good drivers may have been in accidents or received convictions as a result of acts they seldom commit. These are expected to have few accidents in a subsequent period. Others in this group are in fact poor drivers and are expected to have a large number of accidents in the subsequent period. Thus the population of drivers who are in the same age group, sex and driving record as Mr. Smith in the first two year period, in fact have very different expected numbers of accidents. However, to the model, these people appear to be the same and thus are assigned the same *estimated expected number of accidents.*

The model reflects the diversity of real accident potential in this group, by not only telling us the *average* expected number of accidents, but also the *variance* of expected number of accidents in this group. Thus for Mr. Smith and drivers of the same age group, sex and record there is a distribution of expected number of accidents which is estimated by our model. As shown in Figure 12 for this group of drivers, with an average expected number of accidents of 0.25, 60% in reality have an expected number of accidents of 0.22 (hits) or more while 2% at the other end of the distribution have in reality an expected number of accidents of 0.055 or less (false alarms).

Figure 12




Note: These graphs are for the purpose of illustration only and are not meant to accurately represent particular data sets.

Now consider another driver, Ms. Jones, who belongs to a different group of drivers amongst our population of 1000 drivers with the worst records. In this group the average expected number of accidents is different from Mr. Smith's group (though it is still high), and the curve of the distribution of actual expected numbers of accidents is different (See Figure 12). Here it may be that 4% of the drivers have a low expected number of accidents of 0.055 or less (we call these *false alarms*), while 40% have an expected number of accidents of 0.22 or more (which we call *hits*).

In order to determine the total number of hits (drivers with an expected number of accidents of 0.22 or more) in the population of 1000 drivers with the worst records, we add the numbers of drivers in each of the various groups (the Mr. Smith group, the Ms. Jones group etc.) who would have more than 0.22 expected accidents. Let us assume there are 20 drivers in Ms. Jones group, and 50 drivers in Mr. Smith's group. In the case of Mr. Smith group there will be 60% of 20 drivers, or 12 hits. In the case of the Ms. Jones group there will be 40% of 20 drivers, or 8 hits. By adding up the hits we obtain the numbers in Table 11, that is 528 hits in the 1000 worst records selected by model A4, 1568 hits in the next 4000 worst records etc. Similarly, we can add up the false alarms in each of our distributions.

For illustration purposes, models A4 and B4 were selected. (The variables which these use to estimate accident potential are shown in Table 8.) Drivers were ranked in terms of accident potential estimated by each model, based on their record during the first two-year period. Table 11 shows the hits (drivers correctly determined to have accident potential larger than 0.22 accidents/year) for the 10,000 drivers from a population of 5 million Ontario drivers with the highest accident potential as estimated by each model.

As Table 11 shows, in a group of the worst 1000 drivers as selected by model A4, there are 528 hits and 39 false alarms. When drivers are selected by model B4, the number of hits increases to 541 but the number of false alarms correspondingly increases to 45. Thus, there is not much to differentiate the two models for the top 1000 drivers, probably because they consist largely of the same people. In the second 10,000 worst driver records, A4 gives 2679 hits and 933 false alarms while B4 gives 2657 hits and 1110 false alarms. Thus, A4 is not much better than B4 in terms of identifying the hits but is substantially better in terms of calling in fewer drivers which are better than average; A4 tends to have fewer false alarms than B4.

Note that the yield of hits is above 50% in the first 1000 drivers and only ~15% in drivers ranking between 20,000 and 120,000. Similarly, there are only 3-4% false alarms in the top 1000 drivers and this increases to 14-17% in the last row. Thus the larger the group identified, the worse the performance of the net.

Now let us consider another aspect of how our net performs. How many of the drivers in the population who have an unusually high accident potential will slip through the holes? Earlier we showed that there are drivers with bad records who belong to a group with a high average accident potential, but who themselves belong to the end of the distribution where the probability of an accident is low. Similarly there are many drivers with average or good driving records who belong to groups with low average accident potential but

TABLE 11 : **Figures of merit for Models A4, B4**

| Drivers estimated by model to be in | Number of drivers expected to have $m > 0.22$ | | $m < 0.05$ | |
|---|---|---|---|---|
| | Model A4 | Model B4 | Model A4 | Model B4 |
| the top 1,000 | 528 | 541 | 39 | 45 |
| the next 4,000 | 1568 | 1595 | 246 | 289 |
| the next 5,000 | 1601 | 1620 | 390 | 458 |
| the next 10,000 | 2679 | 2657 | 933 | 1110 |
| the next 100,000 | 15987 | 15291 | 14198 | 16928 |
| TOTALS 120,000 | 22363 | 21704 | 15806 | 18830 |

who themselves are in the upper end of the distribution and have a high accident potential. Such individuals will slip through the net.

Looking again at Figure 8, it can be seen that out of 5 million drivers, 90,000 drivers have an accident potential larger than 0.22 accidents/year. Thus, as Table 11 shows, using model A4 to select the 10,000 drivers with the worst records will catch 3697 of the high accident potential drivers; calling in the next 10,000 will identify 2679 more hits. Calling in the next 100,000 will yield another 15,987 hits. Thus even after those 120,000 drivers of 5 million who have the highest accident potential according to model A4 have been selected for treatment, only 22,363 hits can be expected. Of the 90,000 drivers in the population who have an unusually high accident potential (>0.22), still 67,637 remain unidentified. One would have to call in the whole driver population before all the hits would be identified.

Table 12 compares performance among the 16 models, and the current demerit point system, in terms of hits and false alarms for the worst 10,000 drivers identified by each model. It should be noted that, while there will always be considerable overlap between groups of drivers identified by different models, there also will be systematic differences. Thus, for example, the *use of model series A and B will lead to groups which contain more truck drivers than the current system,* simply because the current system does not assign any points for truck weight or truck dimension offenses, while models A and B weigh these heavily.

While comparison in terms of hits and false alarms is good for purposes of illustration, it depends on a rather arbitrary definition of what is to be considered an "unusually high" accident potential. A more comprehensive way to characterize the performance of different models is by continuous curves, as shown in Figure 13.

In Figure 13, accident potential is measured on the horizontal axis. The lowest curve represents the current demerit point scheme. In a group of 10,000 drivers who in a population of 5 million have the most demerit points, one can expect to find 2800 who have an accident potential above 0.2 accidents per year. The highest curves represent models A4 and B4. In a group of 10,000 drivers who in a population of 5 million have the highest estimated accident potential by model A4, one can expect to find some 4200 drivers who have an accident potential above 0.2 accidents per year. Thus, the higher the curve, the better the net.

While the current demerit point scheme is clearly inferior to the new schemes, there is not much to distinguish between the other four models in Figure 13. A4 and B4 give a separate weight to each of 14 convictions and are somewhat better than C4 and D4 which assign the same weight to all convictions. A4 (which uses age and gender information) is slightly better than B4 where accident potential is less than 0.15 accidents/year. B4 is slightly better than A4 for accident potential greater than 0.15 accidents/year.

In Figure 14 we show a second group of 10,000 drivers, those who rank in the 20,000 to 30,000 worst records. That is, these drivers' records are bad, but not as bad as the 10,000 shown in Figure 13. The difference in the performance of the four models appears to be even less important.

**TABLE 12 : Figures of merit for 10,000 drivers with highest m's (for each model)**

| Model | Number of drivers expected to have $m > 0.22$ | $m < 0.05$ |
|---|---|---|
| A1 | 3258 | 908 |
| A2 | 3691 | 676 |
| A3 | 3449 | 817 |
| A4 | 3698 | 674 |
| B1 | 3331 | 1062 |
| B2 | 3750 | 806 |
| B3 | 3516 | 923 |
| B4 | 3757 | 792 |
| C1 | 2911 | 1024 |
| C2 | 3411 | 756 |
| C3 | 3147 | 922 |
| C4 | 3429 | 752 |
| D1 | 2978 | 1211 |
| D2 | 3441 | 909 |
| D3 | 3155 | 1101 |
| D4 | 3451 | 906 |
| CURRENT DP | 1783 | 1465 |

FIGURE 13

CURRENT DP VS SCHEMES A4,B4,C4,D4

10000 Drivers With Largest Estimated Accident Potential

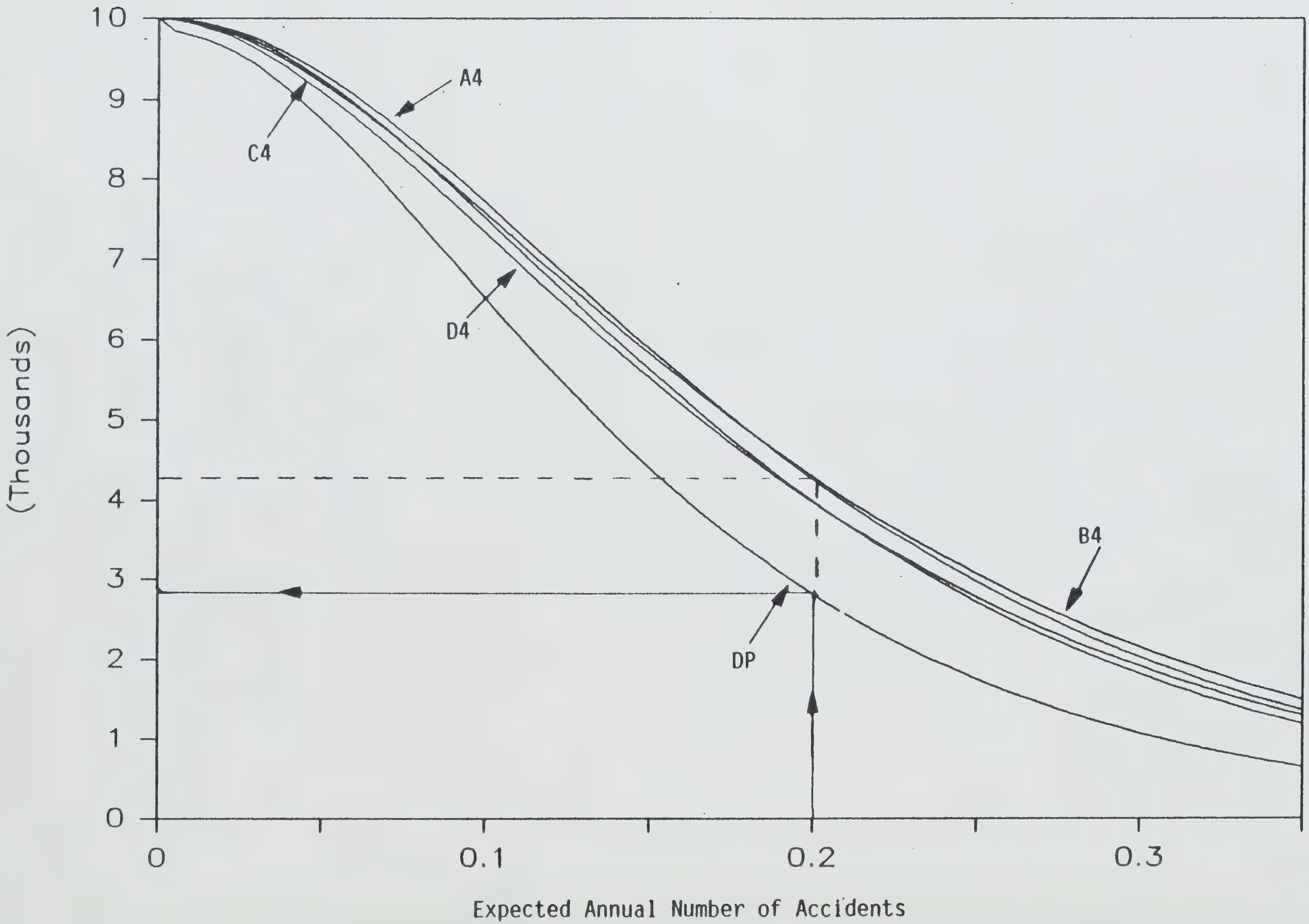
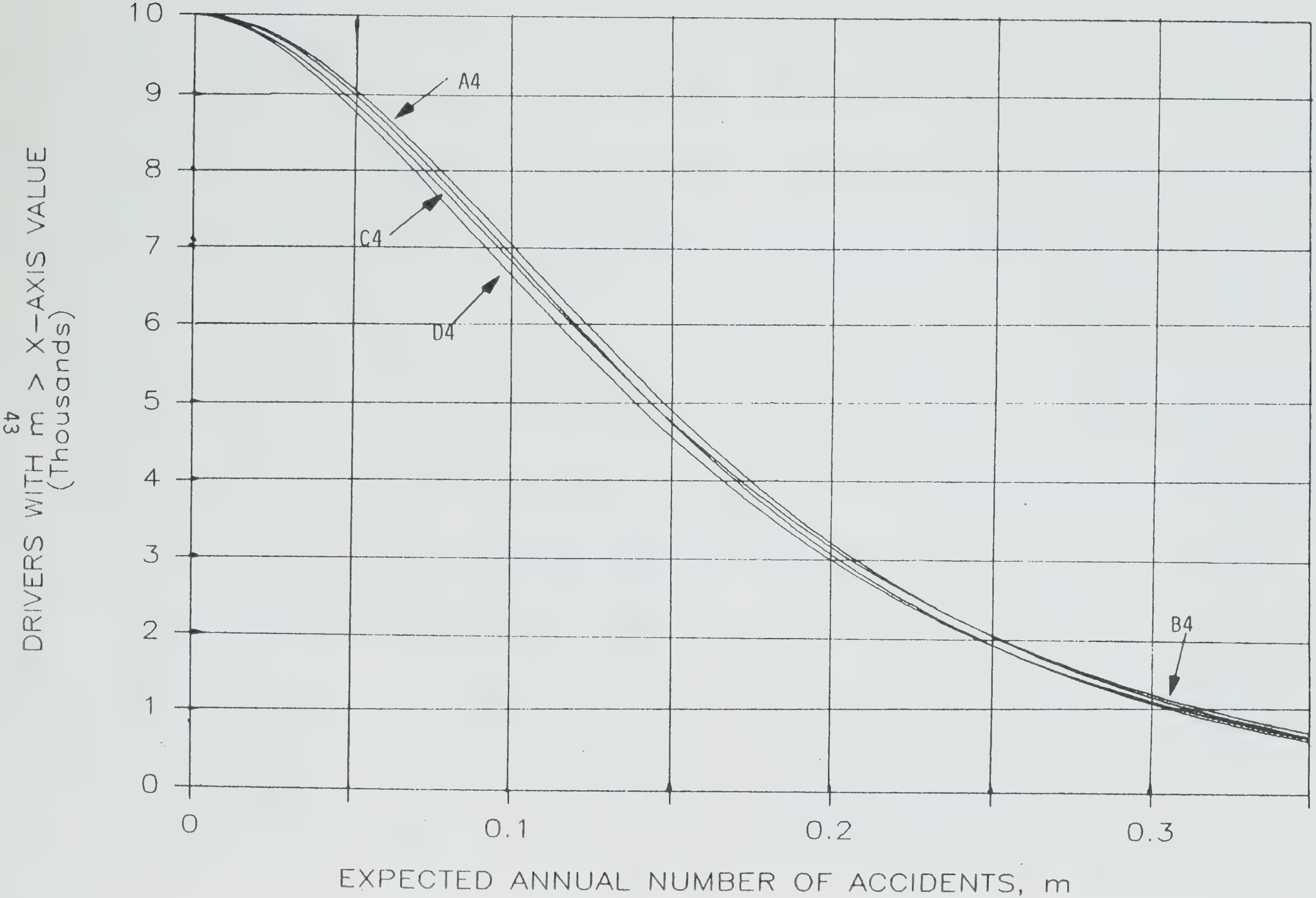


FIGURE 14

RUNS A4,B4,C4,D4

DRIVERS WITH 10000 to 20000 HIGHEST ESTIMATED ACCIDENT POTENTIAL



## 5.0 SUMMARY AND CONCLUSIONS

The purpose of this work was to use a driver's record of convictions and accidents in order to predict, as well as possible, which drivers, based on their past record, are most likely to have an accident in the near future.

Driver Record Sample. A sample of 827,995 records of drivers licensed to drive in Ontario during 1981-1985 has been examined. Each driver record contained information about the driver's gender, age, and details of accidents, convictions, demerit points and suspensions.

Preparatory Analysis. In preparation for analysis, the many hundreds of offense types had to be grouped into a manageable number of categories. We first put in the same group offenses which were similar in nature and then consolidated those offenses which were associated with a similar average number of accidents. It turned out that, for example, drivers who in one year had a single speeding conviction had fewer accidents in the remaining three years than other drivers who had a single conviction in that year for a relatively minor offense such as a missing lamp. This finding may be initially puzzling but, on reflection, helps to interpret later results correctly. It arises partly because not all illegal behaviours lead to convictions at the same rate, partly because some offenses are specific to truck drivers who drive 10-20 times as much as car drivers and tend to have proportionately more accidents, and partly because behaviour which results in a fairly innocuous offense such as a noisy muffler may be of the type which also leads to accidents. Therefore neither the ratio of accidents to convictions nor the "weights" which are later attached to particular offenses are an indication of the gravity of that offense.

Drivers whose license is suspended will curtail their driving to some extent. This is why, during the period of suspension, one should expect some reduction in the number of accidents in which they are involved. However, the extent to which driving is curtailed is unknown. To assume that suspended drivers stop driving would introduce a bias into the analysis; assuming that they continue to drive would cause another bias. To protect the integrity of the results, drivers who were suspended had to be removed from the analysis. Therefore, our conclusions apply directly only to drivers who have not been suspended. The extension to drivers who were suspended under the present demerit point system is therefore an extrapolation.

Alternate Weighting Schemes. We have examined 16 models to estimate the expected number of future accidents for a driver based on age, gender, convictions and accidents. The models differ from each other in the information which is used. Some make use of age and gender, others do not; in some, each of 14 types of convictions is given a different weight, in others all convictions have the same weight; in some, at-fault accidents are counted separately from not-at-fault accidents, in some they are lumped together. All 16 models have a common structure, that of a "weighed sum" of convictions, and in some models, accidents. The basis is always a 17-20 year old male with no accidents or convictions in the first two years. Thus, in one of the models, these drivers are expected to have 0.176 accidents in the second two year period. For being female one subtracts 0.061, for being 24 years old one subtracts 0.039, for having two speeding convictions one adds 2 x 0.027 for having an accident one adds 0.058, and so on. The result is an estimate of the accident potential of a driver with specific age, gender and

record of convictions and accidents. We also estimate the distribution of accident potential in the population of drivers with given traits. We make use of this distribution to describe the performance of alternative models.

Measures of Performance. Two measures of performance were used to judge the quality of a model or weighting scheme. The first measure of performance is the *number of period two accidents* in a group of drivers of fixed size as identified by each model or weighting scheme on the basis of their first period record. The second measure of performance is the number of "hits" and the number of "false alarms" expected to occur in groups of fixed size as selected by the alternative models.

Comparison of the Current Demerit Point System and Alternative Schemes. By the first measure of performance we find that those 10,000 drivers who in the first two year period had most demerit points, recorded during the second two year period 1452 accidents per year. Those 10,000 drivers who in the first two year period had the most accidents, recorded in the subsequent two year period 1828 accidents per year. A third group of 10,000 drivers, those who by model A2 had the highest accident potential when calculated on the basis of first period data, recorded 2116 accidents per year in the second period. Thus, selection by model A2 gives a richer catch than either selection by previous accidents or by the current demerit points. On this score, model A2 seems to perform best.

Several conclusions emerge. First, one can do better than to use the current demerit point weights. Second, it is important to make use of the driver's record of accidents. Third, the more drivers that are identified, the lesser the "yield". Thus, the top 1000 drivers have an accident rate of ~0.3 accidents/year which is approximately 6 times the population average; for the first 10,000 drivers the average accident rate is ~ 0.2 and so on.

We now turn to the examination of the second measure of performance. Not all drivers have the same expected number of accidents per year. Some drive more, some less, many drivers are prudent, some take unwise risks. Based on the accident data we show how many drivers in Ontario have what expected number of accidents. Thus, for example, of 5 million drivers, some 90,000 have an expected number of accidents three standard deviations above the average for the population. It is these "high-accident-potential" drivers which a demerit point scheme aims to identify. A two year record of convictions and accidents is just too short to estimate a driver's expected number of accidents with accuracy. This is because a given two year period may not truly reflect a driver's typical driving behaviour. This is why some of those identified by the model as having the highest expected number of accidents, turn out in reality to be just average drivers. Conversely, this is why most high accident potential drivers may not have, in two years, a record which identifies them as such. We showed, for example, that of the 10,000 drivers who by the "richest" model (A4) were estimated to have the highest expected number of accidents, 3698 (Table 12) have an accident potential in excess of three standard deviations above the mean for the population. These are the hits. At the same time, 674 of those 10,000 were average drivers or better. Were we to identify a different group of 10,000 drivers, those who in a two year period had the most demerit points (using the current scheme), we would have found 1783 hits (Table 11), instead of 3698 by model A4, and 1465 false alarms, instead of 674 by model A4. Thus, the model A4 is considerably better than the current demerit point

instead of 3698 by model A4, and 1465 false alarms, instead of 674 by model A4. Thus, the model A4 is considerably better than the current demerit point scheme. It identifies more high-accident-potential drivers and fewer drivers who are better-than-average.

Since A4 uses age and gender data, it is not fair to compare it to the current demerit point scheme. A fair comparison is with model B1 (no age, gender or accident information used) or B2 (accident information used but no age or gender). The performance of these three models for the 10,000 drivers with highest estimated accident potential is shown below:

| | Hits >0.22 | False Alarms <0.055 acc./yr. |
|---|---|---|
| Current Demerit Points | 1783 | 1465 |
| B1 | 3331 | 1062 |
| B2 | 3750 | 806 |

Comparison of Equal Point Schemes and Separate Weight Schemes. Finally it may be of interest to note that little is gained by giving different numbers of points to different offenses. Model D1 uses simply one-point-per-conviction and no accident data; model D2 uses one-point-per-conviction and 1.88 points per accident. Model D2 is only slightly worse than model B2 which assigns different numbers of points to each of fourteen offense classes.

| | Hits >0.22 | False Alarms <0.055 acc./yr. |
|---|---|---|
| Current Demerit Points | 1783 | 1465 |
| D1 | 2978 | 1211 |
| D2 | 3441 | 909 |

In summary, if the purpose of a demerit point system is to identify drivers who are most likely to have an accident, the scheme used now is not as efficient as alternative schemes would be. Even by giving equal weights to all convictions and a weight of ~2 to an accident (D2), one can do much better. It is important to use data about accident involvement, but it does not pay to differentiate between at-fault and not-at-fault accidents.

For the top 5000 (or so) drivers, it makes little difference whether separate weights are assigned to different offenses. However, for the next 100,000 drivers, separate weights improve performance (in terms of predicting the number of future accidents) by a few percentage points. Separate weights help to increase the number of hits and to reduce the number of false alarms by some 10%.

Comparison of Schemes Using Age and Gender and Schemes That Do Not. For the top 5000 or so drivers, the inclusion of age and gender information appears to be unimportant. For the next 100,000 drivers consideration of age and gender improves performance (in terms of predicting future accidents).

Limitations of any Demerit Point Scheme. With all this, one has to keep in mind that if only a few drivers are identified (say about 10,000) 30-40% of those will be genuine high-accident-potential drivers and only 6-10% will be falsely identified better-than-average drivers. However, only 3% of all high-accident-potential drivers in the population will be in this group of 10,000 drivers. It does not help much to increase the size of the group because performance deteriorates with size. Thus, in a group of 120,000 drivers only ~19% are genuinely high-accident-potential whereas 13-16% are falsely identified. Even when as many as 120,000 drivers are identified by the richest model, only 22,363 of the 90,000 "high-accident-potential" drivers are caught in the net.

Further Improvements. The performance of models for the estimation of a person's accident potential can be further improved. We think that consideration should be given to a system which nearly continuously tracks a person's accident potential. If during a certain period of time (measured in weeks) the driver did not acquire a conviction and was not involved in an accident, his or her estimated accident potential would be revised downward. If during that period of time, convictions or accidents were recorded, the estimated accident potential would be correspondingly revised upward. A person's aging, the general accident trend and seasonal variation would also be reflected in these revisions. In this manner, a person's current estimated accident potential could be made a reflection of his or her entire driving history. In such a scheme, there is no need to specify an arbitrary period of time after which points are forgiven.

In the models developed so far, involvement in an accident adds a fixed amount to a driver's accident potential. Under the newly suggested scheme, an accident for a person with an already high accident potential would be weighted more heavily. In general a "revision" scheme of this nature relies on solid mathematical logic and is expected to perform better than other possible schemes.

# APPENDIX 1

## Recalculation of the Estimated m Associated With Each Offense Type According to a Standardized Age-Gender Distribution

## Recalculation of the Estimated m Associated With Each Offense Type According to a Standardized Age-Gender Distribution

The clustering of all possible offense types into a manageable number of groups was accomplished in several steps. The first step was to combine the offense types which are quite similar in nature into a smaller number of categories. A total of 45 such categories were established in our discussions with MTO in April 1987. These consisted of 38 categories of moving violations, 3 for vehicle related offenses, and 4 for non-moving, administrative violations.

This number of categories was still considered too large for practical purposes. In addition it was expected that some categories would still contain too few convictions. Thus an attempt was made to further group similar categories. This time, the similarity or difference of convictions was indicated by the contribution of each conviction in explaining a driver's accident record. Some re-shuffling of convictions within the original categories was also done on this basis.

The object of the exercise was to identify drivers with one and only one conviction of a given type (or category) in one calendar year, and for each conviction type, obtain the mean (m) and the [var(m)] of accidents in the other 3 years. These estimates were adjusted so that the age-sex distribution of drivers in each conviction class was the same as that for all drivers who had one conviction (of any type) in any of the 4 years 1981-1984.

Step 1: Drivers with one and only one conviction (*of any type*) in any year were identified and grouped according to age and sex. This was designated the base population. The proportion of drivers in each age-sex group was then calculated. Table A1.1 shows, for example, that 8154 such drivers were males aged 30 at the time of the conviction, accounting for 0.0323 of the base population. The number 0.0323 is the weight that was applied in step 2.

Step 2: Drivers with one and only one conviction (*of a given type*) in any year were identified and grouped according to age and sex. For each group, the proportion and number of drivers, the number and sum of squares of accidents in the other 3 years was calculated. For example, Table A1.2 shows that of the 8154 30-year old male drivers (Table A1.1) having only one conviction in any year, 332 had running red light convictions. These 332 drivers represent 0.02595 of the sub-population of drivers whose one conviction in a year was Type m13, and had 99 accidents (Sum of squares = 149) in the other 3 years.

Step 3: For a given conviction type the number of accidents and sum of squares for each age-sex group were weighted and aggregated as follows. For an age-sex group, the ratio of the population weight to the sub-population weight was applied to number of accidents and sum of squares for the group. Thus, for 30 year old males, the ratio is 0.323/0.2595 = 1.244 for "run red light" convictions, shown in column 4 of Table A1.2; the number of accidents (99) and the sum of squares (149) are "factored" by 1.244. The factored numbers for each age group are summed and the sums are divided by sub-population size to get the (weighted) mean values for the sub-population. Table A1.3 shows that of all drivers in the "base" population, 13731 had "run red light" convictions and had 4270 accidents in 3 years. The method

described above gives a weighted mean of 0.313 accidents per driver [E(m)] in this class.

Step 4: 95% confidence limits for the estimates of E(m) were calculated. These are also shown in Table A1.3.

Step 5: Steps 2 to 4 were repeated for speeding convictions placed into categories according to the following guidelines:

(a) Reflecting the current demerit system, drivers were grouped regardless of speed limit according to whether they had exceeded the speed limit by less than 16 km/h, 16-29 km/h, 30-49 km/h or more than 49 km/h.

(b) For drivers grouped according to (a), sub-groups were identified for speed-limit groups of 20-40 km/h, 50-60 km/h and 80-100 km/h.

Table A1.4 provides similar information to Table A1.3 but for the various types of speeding convictions.

**TABLE A1.1: Distribution of drivers with one conviction in any year**

| | MALES | | | | FEMALES | | | |
|---|---|---|---|---|---|---|---|---|
| Age | Drivers | Proportion | Accs. | Sum of Squares | Drivers | Proportion | Accs. | Sum of Squares |
| 17 | 1594 | 0.006309 | 534 | 961 | 260 | 0.001029 | 56 | 73 |
| 18 | 4534 | 0.017946 | 1810 | 3990 | 961 | 0.003804 | 186 | 306 |
| 19 | 7712 | 0.030525 | 3075 | 8182 | 1691 | 0.006693 | 395 | 699 |
| 20 | 10034 | 0.039716 | 4247 | 12502 | 2353 | 0.009313 | 527 | 896 |
| 21 | 11253 | 0.044541 | 4572 | 14375 | 2766 | 0.010948 | 614 | 1505 |
| 22 | 11558 | 0.045748 | 4734 | 13799 | 2879 | 0.011395 | 628 | 1144 |
| 23 | 11253 | 0.044541 | 4238 | 13090 | 3034 | 0.012009 | 615 | 1422 |
| 24 | 10740 | 0.042510 | 4019 | 12121 | 2899 | 0.011475 | 572 | 952 |
| 25 | 10254 | 0.040586 | 3474 | 10120 | 2873 | 0.011372 | 560 | 1050 |
| 26 | 9756 | 0.038615 | 3402 | 9553 | 2743 | 0.010857 | 503 | 971 |
| 27 | 9284 | 0.036747 | 3065 | 8657 | 2670 | 0.010568 | 449 | 849 |
| 28 | 8846 | 0.035013 | 2775 | 8016 | 2583 | 0.010224 | 432 | 796 |
| 29 | 8361 | 0.033094 | 2534 | 7125 | 2669 | 0.010564 | 520 | 981 |
| 30 | 8154 | 0.032274 | 2479 | 7070 | 2570 | 0.010172 | 461 | 827 |
| 31 | 7895 | 0.031249 | 2371 | 6021 | 2537 | 0.010042 | 426 | 674 |
| 32 | 7013 | 0.027758 | 2079 | 5416 | 2463 | 0.009749 | 437 | 846 |
| 33 | 6126 | 0.024247 | 1849 | 4759 | 2240 | 0.008866 | 430 | 797 |
| 34 | 5143 | 0.020357 | 1519 | 4110 | 2185 | 0.008648 | 351 | 678 |
| 35 | 4583 | 0.018140 | 1352 | 3397 | 1969 | 0.007794 | 374 | 747 |
| 36 | 3762 | 0.014890 | 1175 | 3013 | 1663 | 0.006582 | 309 | 551 |
| 37 | 3376 | 0.013363 | 976 | 2702 | 1589 | 0.006289 | 288 | 609 |
| 38 | 2986 | 0.011819 | 912 | 2716 | 1313 | 0.005197 | 260 | 537 |
| 39 | 2679 | 0.010604 | 858 | 2500 | 1172 | 0.004639 | 228 | 407 |
| 40 | 2366 | 0.009365 | 687 | 1762 | 1017 | 0.004025 | 187 | 338 |
| 41 | 2252 | 0.008914 | 647 | 1574 | 935 | 0.003701 | 155 | 320 |
| 42 | 2024 | 0.008011 | 610 | 1596 | 850 | 0.003364 | 147 | 235 |
| 43 | 1814 | 0.007180 | 479 | 1150 | 792 | 0.003135 | 131 | 189 |
| 44 | 1709 | 0.006764 | 516 | 1260 | 597 | 0.002363 | 100 | 166 |
| 45 | 1530 | 0.006056 | 410 | 875 | 622 | 0.002462 | 122 | 185 |
| 46 | 1380 | 0.005462 | 406 | 888 | 537 | 0.002126 | 81 | 129 |
| 47 | 1312 | 0.005193 | 384 | 833 | 465 | 0.001841 | 80 | 148 |
| 48 | 1134 | 0.004488 | 337 | 875 | 454 | 0.001797 | 83 | 118 |
| 49 | 1086 | 0.004299 | 333 | 952 | 404 | 0.001599 | 75 | 130 |
| 50 | 951 | 0.003764 | 283 | 905 | 320 | 0.001267 | 50 | 85 |
| 51 | 882 | 0.003491 | 244 | 640 | 318 | 0.001259 | 44 | 61 |
| 52 | 846 | 0.003349 | 200 | 499 | 295 | 0.001168 | 46 | 46 |
| 53 | 762 | 0.003016 | 209 | 428 | 252 | 0.000997 | 42 | 65 |
| 54 | 663 | 0.002624 | 233 | 767 | 297 | 0.001176 | 47 | 76 |
| 55 | 617 | 0.002442 | 164 | 365 | 233 | 0.000922 | 59 | 98 |
| 56 | 565 | 0.002236 | 174 | 356 | 207 | 0.000819 | 31 | 62 |
| 57 | 492 | 0.001947 | 133 | 269 | 188 | 0.000744 | 31 | 44 |
| 58 | 460 | 0.001821 | 98 | 185 | 173 | 0.000685 | 43 | 79 |
| 59 | 376 | 0.001488 | 98 | 234 | 138 | 0.000546 | 29 | 58 |
| 60 | 372 | 0.001472 | 106 | 221 | 145 | 0.000574 | 32 | 52 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 61 | 297 | 0.001176 | 78 | 168 | 114 | 0.000451 | 16 | 33 |
| 62 | 295 | 0.001168 | 91 | 226 | 94 | 0.000372 | 12 | 19 |
| 63 | 221 | 0.000875 | 68 | 159 | 82 | 0.000325 | 9 | 11 |
| 64 | 177 | 0.000701 | 64 | 113 | 88 | 0.000348 | 15 | 27 |
| 65 | 159 | 0.000629 | 40 | 88 | 61 | 0.000241 | 5 | 8 |
| 66 | 140 | 0.000554 | 31 | 57 | 55 | 0.000218 | 10 | 16 |
| 67 | 113 | 0.000447 | 37 | 154 | 52 | 0.000206 | 13 | 22 |
| 68 | 104 | 0.000412 | 20 | 44 | 43 | 0.000170 | 7 | 13 |
| 69 | 69 | 0.000273 | 10 | 16 | 40 | 0.000158 | 9 | 22 |
| 70 | 73 | 0.000289 | 27 | 57 | 25 | 0.000099 | 10 | 14 |
| 71 | 61 | 0.000241 | 12 | 15 | 18 | 0.000071 | 1 | 1 |
| 72 | 56 | 0.000222 | 20 | 29 | 19 | 0.000075 | 2 | 2 |
| 73 | 26 | 0.000103 | 9 | 15 | 10 | 0.000040 | 6 | 10 |
| 74 | 40 | 0.000158 | 21 | 63 | 18 | 0.000071 | 0 | 0 |
| 75 | 19 | 0.000075 | 2 | 2 | 18 | 0.000071 | 9 | 13 |
| 76 | 38 | 0.000150 | 12 | 33 | 14 | 0.000055 | 2 | 2 |
| 77 | 36 | 0.000142 | 14 | 167 | 7 | 0.000028 | 1 | 1 |
| 78 | 29 | 0.000115 | 11 | 75 | 10 | 0.000040 | 3 | 5 |
| 79 | 20 | 0.000079 | 4 | 9 | 11 | 0.000044 | 3 | 3 |
| 80 | 30 | 0.000119 | 6 | 14 | 4 | 0.000016 | 2 | 5 |
| 81 | 21 | 0.000083 | 8 | 12 | 1 | 0.000004 | 1 | 1 |
| 82 | 14 | 0.000055 | 5 | 7 | 3 | 0.000012 | 0 | 0 |
| 82+ | 9 | 0.000036 | 1 | 1 | 2 | 0.000008 | 0 | 0 |

TABLE A1.2: Drivers with 1 "run red light" conviction in any year

| | MALES | | | | | FEMALES | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Proportion | | | | | Proportion | | | |
| Age | No. | For class | Relative to all | Accs. | Sum Sq. | No. | For class | Relative to all | Accs. | Sum Sq. |
| 17 | 84 | 0.00657 | 0.961 | 21 | 21 | 15 | 0.00117 | 0.878 | 4 | 6 |
| 18 | 247 | 0.01931 | 0.929 | 91 | 121 | 66 | 0.00516 | 0.737 | 13 | 13 |
| 19 | 422 | 0.03299 | 0.925 | 159 | 244 | 121 | 0.00946 | 0.708 | 24 | 32 |
| 20 | 497 | 0.03885 | 1.022 | 183 | 293 | 130 | 0.01016 | 0.916 | 28 | 34 |
| 21 | 571 | 0.04463 | 0.998 | 234 | 410 | 167 | 0.01305 | 0.839 | 27 | 33 |
| 22 | 546 | 0.04268 | 1.072 | 195 | 295 | 202 | 0.01579 | 0.722 | 31 | 39 |
| 23 | 501 | 0.03916 | 1.137 | 150 | 211 | 149 | 0.01165 | 1.031 | 15 | 17 |
| 24 | 492 | 0.03846 | 1.105 | 163 | 329 | 161 | 0.01259 | 0.912 | 18 | 20 |
| 25 | 436 | 0.03408 | 1.191 | 120 | 163 | 159 | 0.01243 | 0.915 | 30 | 36 |
| 26 | 428 | 0.03346 | 1.154 | 143 | 244 | 142 | 0.01110 | 0.978 | 16 | 18 |
| 27 | 374 | 0.02923 | 1.257 | 105 | 196 | 138 | 0.01079 | 0.980 | 25 | 25 |
| 28 | 375 | 0.02931 | 1.194 | 80 | 178 | 124 | 0.00969 | 1.055 | 22 | 26 |
| 29 | 328 | 0.02564 | 1.291 | 102 | 162 | 129 | 0.01008 | 1.048 | 24 | 34 |
| 30 | 332 | 0.02595 | 1.244 | 99 | 149 | 143 | 0.01118 | 0.910 | 25 | 31 |
| 31 | 313 | 0.02447 | 1.277 | 57 | 75 | 112 | 0.00875 | 1.147 | 16 | 16 |
| 32 | 298 | 0.02329 | 1.192 | 83 | 115 | 143 | 0.01118 | 0.872 | 21 | 25 |
| 33 | 261 | 0.02040 | 1.188 | 66 | 98 | 131 | 0.01024 | 0.866 | 29 | 43 |
| 34 | 259 | 0.02025 | 1.006 | 67 | 90 | 110 | 0.00860 | 1.006 | 10 | 10 |
| 35 | 220 | 0.01720 | 1.055 | 59 | 79 | 108 | 0.00844 | 0.923 | 15 | 15 |
| 36 | 188 | 0.01470 | 1.013 | 61 | 111 | 103 | 0.00805 | 0.818 | 14 | 14 |
| 37 | 185 | 0.01446 | 0.924 | 47 | 63 | 105 | 0.00821 | 0.766 | 11 | 11 |
| 38 | 152 | 0.01188 | 0.995 | 44 | 76 | 83 | 0.00649 | 0.801 | 19 | 21 |
| 39 | 147 | 0.01149 | 0.923 | 41 | 55 | 59 | 0.00461 | 1.006 | 4 | 4 |
| 40 | 139 | 0.01087 | 0.862 | 44 | 72 | 82 | 0.00641 | 0.628 | 12 | 12 |
| 41 | 117 | 0.00915 | 0.975 | 27 | 35 | 58 | 0.00453 | 0.816 | 8 | 12 |
| 42 | 105 | 0.00821 | 0.976 | 18 | 22 | 66 | 0.00516 | 0.652 | 5 | 5 |
| 43 | 101 | 0.00789 | 0.909 | 27 | 45 | 61 | 0.00477 | 0.657 | 12 | 14 |
| 44 | 81 | 0.00633 | 1.068 | 18 | 22 | 39 | 0.00305 | 0.775 | 8 | 10 |
| 45 | 102 | 0.00797 | 0.760 | 21 | 25 | 56 | 0.00438 | 0.562 | 13 | 21 |
| 46 | 89 | 0.00696 | 0.785 | 18 | 20 | 36 | 0.00281 | 0.755 | 1 | 1 |
| 47 | 79 | 0.00618 | 0.841 | 24 | 34 | 38 | 0.00297 | 0.620 | 4 | 6 |
| 48 | 67 | 0.00524 | 0.857 | 17 | 33 | 41 | 0.00320 | 0.561 | 7 | 7 |
| 49 | 52 | 0.00406 | 1.058 | 9 | 11 | 34 | 0.00266 | 0.602 | 5 | 5 |
| 50 | 54 | 0.00422 | 0.892 | 17 | 25 | 28 | 0.00219 | 0.579 | 6 | 10 |
| 51 | 56 | 0.00438 | 0.798 | 13 | 17 | 28 | 0.00219 | 0.575 | 3 | 3 |
| 52 | 63 | 0.00492 | 0.680 | 11 | 17 | 22 | 0.00172 | 0.679 | 5 | 5 |
| 53 | 42 | 0.00328 | 0.919 | 7 | 7 | 17 | 0.00133 | 0.750 | 2 | 2 |
| 54 | 42 | 0.00328 | 0.799 | 17 | 31 | 33 | 0.00258 | 0.456 | 2 | 2 |
| 55 | 44 | 0.00344 | 0.710 | 10 | 16 | 20 | 0.00156 | 0.590 | 4 | 6 |
| 56 | 30 | 0.00235 | 0.954 | 7 | 7 | 15 | 0.00117 | 0.698 | 2 | 2 |
| 57 | 36 | 0.00281 | 0.692 | 3 | 3 | 18 | 0.00141 | 0.529 | 5 | 5 |
| 58 | 30 | 0.00235 | 0.777 | 6 | 6 | 10 | 0.00078 | 0.876 | 4 | 8 |
| 59 | 30 | 0.00235 | 0.635 | 8 | 8 | 9 | 0.00070 | 0.776 | 0 | 0 |
| 60 | 31 | 0.00242 | 0.607 | 8 | 20 | 9 | 0.00070 | 0.816 | 1 | 1 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 61 | 16 | Ø.ØØ125 | Ø.94Ø | 5 | 7 | 12 | Ø.ØØØ94 | Ø.481 | 3 | 5 |
| 62 | 28 | Ø.ØØ219 | Ø.534 | 3 | 3 | 7 | Ø.ØØØ55 | Ø.68Ø | 1 | 1 |
| 63 | 2Ø | Ø.ØØ156 | Ø.56Ø | 4 | 6 | 6 | Ø.ØØØ47 | Ø.693 | Ø | Ø |
| 64 | 12 | Ø.ØØØ94 | Ø.747 | 3 | 3 | 4 | Ø.ØØØ31 | 1.113 | Ø | Ø |
| 65 | 13 | Ø.ØØ1Ø2 | Ø.619 | 2 | 2 | 6 | Ø.ØØØ47 | Ø.514 | Ø | Ø |
| 66 | 12 | Ø.ØØØ94 | Ø.591 | 4 | 6 | 2 | Ø.ØØØ16 | 1.394 | 1 | 1 |
| 67 | 8 | Ø.ØØØ63 | Ø.715 | Ø | Ø | 3 | Ø.ØØØ23 | Ø.878 | 1 | 1 |
| 68 | 11 | Ø.ØØØ86 | Ø.479 | 1 | 1 | 2 | Ø.ØØØ16 | 1.Ø87 | Ø | Ø |
| 69 | 2 | Ø.ØØØ16 | 1.746 | Ø | Ø | 3 | Ø.ØØØ23 | Ø.674 | Ø | Ø |
| 7Ø | 5 | Ø.ØØØ39 | Ø.739 | Ø | Ø | 2 | Ø.ØØØ16 | Ø.633 | 1 | 1 |
| 71 | 7 | Ø.ØØØ55 | Ø.44Ø | 2 | 2 | 2 | Ø.ØØØ16 | Ø.454 | Ø | Ø |
| 72 | 5 | Ø.ØØØ39 | Ø.568 | Ø | Ø | 2 | Ø.ØØØ16 | Ø.48Ø | 1 | 1 |
| 73 | 2 | Ø.ØØØ16 | Ø.659 | Ø | Ø | Ø | Ø. | Ø.48Ø | Ø | Ø |
| 74 | 1 | Ø.ØØØØ8 | 2.Ø21 | 1 | 1 | 1 | Ø.ØØØØ8 | Ø.9Ø8 | Ø | Ø |
| 75 | 1 | Ø.ØØØØ8 | Ø.959 | Ø | Ø | Ø | Ø. | Ø.9Ø8 | Ø | Ø |
| 76 | 5 | Ø.ØØØ39 | Ø.384 | 1 | 1 | 4 | Ø.ØØØ31 | Ø.176 | 1 | 1 |
| 77 | 4 | Ø.ØØØ31 | Ø.454 | Ø | Ø | 3 | Ø.ØØØ23 | Ø.119 | Ø | Ø |
| 78 | 7 | Ø.ØØØ55 | Ø.21Ø | 3 | 5 | Ø | Ø. | Ø.119 | Ø | Ø |
| 79 | 1 | Ø.ØØØØ8 | 1.Ø11 | 2 | 4 | 2 | Ø.ØØØ16 | Ø.281 | Ø | Ø |
| 8Ø | 3 | Ø.ØØØ23 | Ø.5Ø7 | Ø | Ø | Ø | Ø. | Ø.281 | Ø | Ø |
| 81 | 1 | Ø.ØØØØ8 | 1.Ø62 | Ø | Ø | Ø | Ø. | Ø.281 | Ø | Ø |
| 82 | 1 | Ø.ØØØØ8 | Ø.7Ø4 | 1 | 1 | 1 | Ø.ØØØØ8 | Ø.154 | Ø | Ø |

TABLE A1.3: **Accidents for Drivers with 1 Conviction in 1 Year**

| Category | Brief Description | No. of Drivers | 3 yr. Accs. | Weighted Mean | 95% Limits Upper | Lower |
|---|---|---|---|---|---|---|
| n1 | Minor neglect, licenses, permits | 6495 | 2918 | 0.434 | 0.445 | 0.422 |
| n2 | Neglect, insurance, permits, etc. | 1589 | 719 | 0.414 | 0.438 | 0.392 |
| n3 | License suspended, HTA | 874 | 454 | 0.424 | 0.456 | 0.394 |
| n4 | Learners | 34 | 18 | 0.343 | 0.502 | 0.212 |
| v1 | Minor veh.; lamps, noise | 2954 | 1498 | 0.468 | 0.485 | 0.451 |
| v2 | Brakes, tires, unsafe vehicle | 946 | 451 | 0.400 | 0.430 | 0.371 |
| v3 | Comm. veh; size & weights | 503 | 369 | 0.542 | 0.583 | 0.500 |
| m1 | Seat belt | 12337 | 4858 | 0.376 | 0.384 | 0.368 |
| m2 | Speeding | 173592 | 55211 | 0.319 | 0.321 | 0.317 |
| m3 | Careless driving | 902 | 342 | 0.327 | 0.357 | 0.299 |
| m4 | Slow driving | 45 | 11 | 0.119 | 0.237 | 0.055 |
| m8 | STOP sign, ROW violations | 14024 | 3935 | 0.288 | 0.295 | 0.281 |
| m9 | PXO violations | 1237 | 355 | 0.296 | 0.320 | 0.272 |
| m10 | Turns violations; right, left, U | 18231 | 4942 | 0.283 | 0.289 | 0.277 |
| m11 | Unsafe move; open door | 1649 | 542 | 0.334 | 0.355 | 0.312 |
| m13 | Disobey red light | 13731 | 4270 | 0.313 | 0.321 | 0.306 |
| m14 | Amber light | 3453 | 982 | 0.285 | 0.299 | 0.271 |
| m15 | Advance green | 274 | 73 | 0.265 | 0.317 | 0.218 |
| m16 | Fail to share road | 170 | 62 | 0.303 | 0.372 | 0.242 |
| m17 | Passing violations | 1305 | 459 | 0.327 | 0.351 | 0.303 |
| m18 | Wrong-way one way street | 1582 | 458 | 0.284 | 0.306 | 0.264 |
| m19 | Improper driving divided h'way | 2599 | 900 | 0.361 | 0.379 | 0.344 |
| m20 | F.T.C. | 934 | 337 | 0.344 | 0.374 | 0.316 |
| m21 | Emerg. veh., school x'ing | 48 | 15 | 0.159 | 0.280 | 0.084 |
| m22 | R/R crossing violations | 95 | 35 | 0.314 | 0.408 | 0.233 |
| m24 | Headlight beam not lowered | 225 | 71 | 0.260 | 0.318 | 0.209 |
| m25 | Improper parking | 145 | 77 | 0.407 | 0.484 | 0.334 |
| m26 | Fail stop for school bus | 604 | 133 | 0.281 | 0.317 | 0.249 |
| m28 | Disobey traffic signs | 1650 | 529 | 0.322 | 0.344 | 0.301 |
| m29 | Fail report accident | 224 | 73 | 0.266 | 0.324 | 0.215 |
| m30 | Fail remain at scene | 236 | 75 | 0.315 | 0.373 | 0.261 |
| m32 | Dangerous driving C.C.C. | 5 | 2 | 0.010 | 0.421 | 0.000 |
| m33 | Fail remain at accident C.C.C. | 66 | 39 | 0.377 | 0.491 | 0.274 |
| m34 | Dangerous driving C.C.C. | 89 | 46 | 0.281 | 0.376 | 0.202 |
| m35 | Impaired driving C.C.C. | 2381 | 1040 | 0.443 | 0.462 | 0.424 |
| m36 | Fail/refuse breath test C.C.C. | 94 | 37 | 0.218 | 0.306 | 0.149 |
| m37 | Fail or ref. breath test C.C.C. | 120 | 50 | 0.314 | 0.397 | 0.241 |
| m38 | Driving with >80 mgs. alcohol | 3676 | 1502 | 0.386 | 0.401 | 0.371 |
| m41 | Crowding driver seat | 120 | 36 | 0.280 | 0.362 | 0.211 |
| m44 | Radar device in vehicle | 68 | 27 | 0.251 | 0.359 | 0.166 |
| m45 | No safe helmet, motorcycle | 96 | 47 | 0.266 | 0.357 | 0.191 |
| m46 | Fail to signal to stop | 18 | 6 | 0.080 | 0.277 | 0.019 |
| m47 | FTC, commercial vehicle | 67 | 35 | 0.362 | 0.475 | 0.262 |
| m48 | Fail to stop for police officer | 12 | 6 | 0.086 | 0.340 | 0.016 |

TABLE A1.4: Accidents for drivers with 1 speeding conviction in 1 year

| Speed Limit | Above Limit | No. of Drivers | 3 yr. Accs. | Weighted Mean | 95% Limits Upper | Lower |
|---|---|---|---|---|---|---|
| All | 0-15 | 123224 | 33755 | 0.293 | 0.296 | 0.291 |
| All | 16-29 | 79589 | 22479 | 0.286 | 0.289 | 0.283 |
| All | 30-49 | 23891 | 7331 | 0.297 | 0.302 | 0.291 |
| All | >49 | 894 | 371 | 0.315 | 0.344 | 0.286 |
| | | | | | | |
| 20-40 | 0-15 | 24264 | 6307 | 0.288 | 0.293 | 0.283 |
| 50-70 | 0-15 | 80248 | 22037 | 0.294 | 0.297 | 0.291 |
| 80-100 | 0-15 | 18712 | 5411 | 0.292 | 0.298 | 0.286 |
| | | | | | | |
| 20-40 | 16-29 | 5276 | 1413 | 0.281 | 0.293 | 0.270 |
| 50-70 | 16-29 | 39995 | 11427 | 0.293 | 0.297 | 0.288 |
| 80-100 | 16-29 | 34318 | 9639 | 0.281 | 0.285 | 0.276 |
| | | | | | | |
| 20-40 | 30-49 | 683 | 185 | 0.269 | 0.302 | 0.239 |
| 50-70 | 30-49 | 9304 | 2914 | 0.305 | 0.314 | 0.296 |
| 80-100 | 30-49 | 13904 | 4232 | 0.292 | 0.300 | 0.285 |
| | | | | | | |
| 20-40 | >49 | 14 | 8 | 0.186 | 0.432 | 0.064 |
| 50-70 | >49 | 405 | 183 | 0.341 | 0.386 | 0.299 |
| 80-100 | >49 | 475 | 180 | 0.272 | 0.312 | 0.236 |

# APPENDIX 2

## Number of Convictions in Each of the Final 14 Conviction Categories

Appendix 2

1981-1984 CONVICTIONS BY PROPOSED CONVICTION CODE CATEGORIES
(Based on sample of 8000 drivers with record)

| Offence | Code | Pts. | TOTAL CONVICTIONS IN 1981 | 1982 | 1983 | 1984 | OLD ID | Tot. | Acc |
|---|---|---|---|---|---|---|---|---|---|
| Total for all convictions | | | 3580 | 3842 | 3617 | 3270 | | 14209 | 976 |
| **REVISED CATEGORY nn1** | | | | | | | | | |
| Dr. m/v,no valid permit | 10033 | | 0 | 13 | 46 | 68 | n1 | 127 | 2 |
| fail not. ch. address | 10050 | | 0 | 9 | 5 | 5 | n1 | 19 | 3 |
| Fail rep.dam to h'wy prop. | 12760 | | 1 | 1 | 1 | 1 | n1 | 4 | 3 |
| " " " " " " | 12770 | | 1 | 0 | 0 | 1 | n1 | 2 | 2 |
| Fail to have insurance card | 20050 | | 0 | 0 | 23 | 34 | n1 | 57 | 3 |
| " " carry " " | 20060 | | 0 | 0 | 3 | 11 | n1 | 14 | |
| " " " evid. of ins. | 20070 | | 0 | 0 | 2 | 0 | n1 | 2 | |
| " " fail not. addr. ch. | 90810 | | 0 | 7 | 6 | 3 | n1 | 16 | 3 |
| No driver's license | 10190 | | 26 | 54 | 26 | 22 | n2 | 128 | 10 |
| Driv., cond. proh. | 10193 | | 0 | 5 | 4 | 5 | n2 | 14 | 2 |
| Learner unaccompanied | 90700 | | 1 | 0 | 0 | 0 | n4 | 1 | |
| Class R Drive m/c at night | 90710 | | 0 | 1 | 1 | 0 | n4 | 2 | |
| " " Cont. to lic.cond. | 90790 | | 1 | 0 | 0 | 0 | n4 | 1 | |
| **REVISED CATEGORY nn2** | | | | | | | | | |
| Permit unlic. driv. | 10195 | | 5 | 1 | 1 | 0 | n2 | 7 | |
| No lic., fail to ID self | 10214 | | 0 | 1 | 1 | 0 | n2 | 2 | |
| More than 1 license | 13270 | | 0 | 0 | 1 | 1 | n2 | 2 | |
| No insurance | 20010 | | 0 | 0 | 2 | 1 | n2 | 3 | |
| Op. m/v, no insurance | 20011 | | 0 | 0 | 3 | 5 | n2 | 8 | 3 |
| False statem. re. insurance | 20030 | | 0 | 0 | 2 | 0 | n2 | 2 | |
| Alter/deface no. plate | 10100 | | 0 | 0 | 1 | 0 | n2 | 1 | |
| Allow/use altered plates | 10110 | | 0 | 2 | 0 | 1 | n2 | 3 | |
| Plates unlawf. removed | 10120 | | 0 | 0 | 1 | 0 | n2 | 1 | |
| Pos. canc/susp. license | 10222 | | 0 | 0 | 1 | 0 | n2 | 1 | |
| Lend driver license | 10224 | | 0 | 0 | 1 | 0 | n2 | 1 | |
| Fail surr. dr. license | 10228 | | 0 | 1 | 0 | 0 | n2 | 1 | |
| Unlaw. pos. license | 10320 | | 1 | 1 | 0 | 0 | n2 | 2 | |
| Dr. m/v, no valid plates | 10034 | | 0 | 0 | 2 | 7 | n1 | 9 | |
| No valid. tag on plates | 10035 | | 0 | 0 | 5 | 34 | n1 | 39 | |
| Draw trailer, no permit | 10037 | | 0 | 0 | 12 | 22 | n1 | 35 | |
| fail surr. m/v permit | 10038 | | 0 | 0 | 3 | 15 | n1 | 18 | |
| " " trl. " | 10039 | | 0 | 0 | 0 | 2 | n1 | 2 | |
| No plate | 10060 | | 0 | 1 | 0 | 0 | n1 | 1 | |
| No plate, operate m/v | 10063 | | 0 | 29 | 5 | 1 | n1 | 35 | |
| No val. tag on m/v | 10067 | | 0 | 13 | 2 | 0 | n1 | 15 | |

Appendix 2

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Imp. plate pos. m/v | 10070 | 0 | 1 | 0 | 1 | n1 | 2 | |
| Fail apply for permit | 10071 | 0 | 0 | 2 | 1 | n1 | 3 | |
| Draw trl., no plate | 10073 | 0 | 1 | 0 | 0 | n1 | 1 | |
| Imp. plates on veh. | 10130 | 0 | 0 | 2 | 11 | n1 | 13 | |
| Use unauthor. plate val. | 10136 | 0 | 0 | 0 | 1 | n1 | 1 | |
| Expose oth. no. near plate | 10160 | 0 | 1 | 0 | 0 | n1 | 1 | |
| No. on plate not visible | 10170 | 0 | 2 | 0 | 0 | n1 | 2 | |
| Fail to prod. dr. license | 10200 | 0 | 0 | 0 | 1 | n1 | 1 | |
| " " " " " | 10210 | 0 | 89 | 38 | 20 | n1 | 148 | 9 |
| No name on comm. veh. | 11060 | 0 | 0 | 1 | 0 | n1 | 1 | |
| Draw trailer, no plate | 12791 | 0 | 0 | 0 | 2 | n1 | 2 | |
| Fail to carry/prod.permit | 13210 | 0 | 4 | 2 | 0 | n1 | 6 | 1 |
| Fail ret.pl. conv. veh. | 90234 | 0 | 4 | 0 | 1 | n1 | 5 | |
| Dealer plate infraction | 90250 | 0 | 1 | 0 | 0 | n1 | 1 | |
| Fail sign license | 90820 | 0 | 3 | 0 | 2 | n1 | 5 | |
| Dr. lic. susp. H.T.A. | 10332 | 39 | 22 | 25 | 10 | n3 | 96 | 5 |
| " " " " | 10335 | 0 | 0 | 1 | 0 | n3 | 1 | |

**REVISED CATEGORY vv1**

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| No sl-mov-veh sign | 10910 | 0 | 0 | 0 | 1 | v1 | 1 | |
| Improper trailer attachment | 10960 | 3 | 3 | 3 | 1 | v1 | 10 | |
| Imp./insuff./ drvg. lamps | 10420 | 0 | 21 | 24 | 20 | v1 | 65 | 2 |
| Imp. lights, motor cycle | 10423 | 0 | 1 | 2 | 0 | v1 | 3 | |
| Imp. head/drvg. lamps | 10440 | 0 | 1 | 0 | 0 | v1 | 1 | 1 |
| Cov. or coat lamps | 10445 | 0 | 1 | 1 | 1 | v1 | 3 | |
| Imp. ident. lamps | 10480 | 0 | 0 | 0 | 1 | v1 | 1 | |
| Imp. red front lamp | 10500 | 0 | 1 | 1 | 0 | v1 | 2 | |
| Imp. no. plate lamp | 10530 | 0 | 5 | 5 | 6 | v1 | 16 | |
| Imp. park lights | 10540 | 0 | 0 | 1 | 1 | v1 | 2 | |
| Imp. rear lamp on trl. | 10570 | 0 | 4 | 3 | 2 | v1 | 9 | |
| Imp. rr. lamp, obj.>leg. w. | 10580 | 0 | 0 | 1 | 0 | v1 | 1 | |
| Imp. signal devices | 10610 | 0 | 5 | 1 | 0 | v1 | 6 | |
| No mudguards | 10730 | 0 | 1 | 1 | 0 | v1 | 2 | |
| View obstr., sign/poster | 10800 | 0 | 1 | 0 | 0 | v1 | 1 | 1 |
| " " , articles hung | 10810 | 1 | 0 | 0 | 0 | v1 | 1 | |
| Obscure color window | 10815 | 0 | 4 | 2 | 2 | v1 | 8 | |
| Windows obstructed | 10830 | 2 | 0 | 0 | 0 | v1 | 2 | |
| " " | 10840 | 3 | 4 | 1 | 0 | v1 | 8 | 1 |
| Rear window obstructed | 10850 | 1 | 2 | 0 | 1 | v1 | 4 | |
| Def/imp/no muffler | 10860 | 0 | 2 | 6 | 5 | v1 | 13 | |
| Proh. use studded tires | 90520 | 0 | 0 | 0 | 1 | v1 | 1 | |

**REVISED CATEGORY vv2**

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Def./no brakes, m/v | 10650 | 1 | 0 | 1 | 0 | v2 | 2 | |
| " " " , trailer | 10670 | 0 | 0 | 0 | 1 | v2 | 1 | |
| Def. brakes, contr. to reg. | 10680 | 0 | 2 | 2 | 2 | v2 | 6 | 2 |
| Def./imp tires | 10750 | 0 | 1 | 4 | 3 | v2 | 8 | |

Appendix 2

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Use proh./unsafe veh | 10970 | | 0 | 1 | 0 | 0 | v2 | 1 | |
| Refuse exam. unsafe veh. | 10980 | | 4 | 3 | 3 | 4 | v2 | 14 | |
| Drive unsafe veh. | 10990 | | 10 | 6 | 3 | 2 | v2 | 21 | 3 |
| Rm./mod./inop. s. belt ass. | 11095 | | 0 | 5 | 3 | 3 | v2 | 11 | 1 |

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**REVISED CATEGORY vv3**

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Overweight dual-axle | 13060 | 0 | 2 | 0 | 2 | v3 | 4 | |
| Gross veh overweight | 13150 | 0 | 1 | 0 | 1 | v3 | 2 | |
| Overweight during freezeup | 13180 | 0 | 0 | 1 | 0 | v3 | 1 | |
| Over weight excess of perm | 13200 | 0 | 1 | 2 | 3 | v3 | 6 | |
| Insecure load | 11260 | 0 | 5 | 5 | 3 | v3 | 13 | |

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**REVISED CATEGORY vv4**

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Op. veh., fl. displ. dev. | 10993 | 0 | 1 | 0 | 0 | v3 | 1 |
| Imp. war. eq., dis. comm./v | 12420 | 0 | 1 | 0 | 0 | v3 | 1 |
| Not mark overhang load | 11250 | 0 | 0 | 1 | 0 | v3 | 1 |
| Excess veh. width | 11310 | 0 | 0 | 1 | 0 | v3 | 1 |
| Excess len. veh-comb. | 11320 | 0 | 1 | 1 | 1 | v3 | 3 |
| Excess veh. height | 11350 | 0 | 1 | 2 | 0 | v3 | 3 |

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**REVISED CATEGORY ee1**

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Excess fumes/smoke | 10870 | 0 | 2 | 2 | 2 | v1 | 6 |
| Unnecess. noise | 10880 | 0 | 39 | 19 | 16 | v1 | 74 |
| Horn/bell violation | 10890 | 0 | 2 | 1 | 2 | v1 | 5 |
| By-law unnec. noise | 80030 | 0 | 0 | 0 | 1 | v1 | 1 |

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**REVISED CATEGORY mm1**

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Fail yield ROW | 11560 | 3 | 4 | 0 | 0 | 0 | m8 | 4 | 4 |
| Disobey police signal | 11530 | 3 | 0 | 2 | 2 | 1 | m8 | 5 | 0 |
| Disobey stop sign | 11570 | 3 | 0 | 1 | 1 | 1 | m8 | 3 | |
| Fail to stop, intersec. | 11580 | 3 | 146 | 138 | 127 | 78 | m8 | 489 | 20 |
| Fail to yield ROW at stop | 11590 | 3 | 26 | 26 | 18 | 16 | m8 | 86 | 67 |
| Fail stop at intersec. | 11592 | 3 | 0 | 0 | 0 | 12 | m8 | 12 | 2 |
| Fail yield ROW at stop | 11593 | 3 | 0 | 0 | 0 | 4 | m8 | 4 | 3 |
| Fail yield ROW at yield | 11610 | 3 | 4 | 0 | 4 | 2 | m8 | 10 | 7 |
| Fail to yield ROW, Pr. rd. | 11620 | 3 | 18 | 23 | 17 | 10 | m8 | 68 | 54 |
| Fail yld. ROW at inters. | 11875 | 3 | 0 | 0 | 0 | 1 | m8 | 1 | 1 |
| Fail yield ROW | 11910 | 3 | 2 | 4 | 0 | 2 | m8 | 8 | |
| Imp. RT at intersection | 11693 | 2 | 4 | 7 | 6 | 10 | m10 | 27 | 4 |
| Imp. RT multi-ln. h'way | 11703 | 2 | 3 | 4 | 1 | 1 | m10 | 9 | 1 |
| Improper left turn | 11713 | 3 | 19 | 12 | 22 | 19 | m10 | 72 | 68 |
| Imp. LT at intersection | 11723 | 2 | 10 | 14 | 15 | 16 | m10 | 55 | 7 |
| Improper left turn | 11733 | 2 | 2 | 2 | 4 | 0 | m10 | 8 | 1 |
| Proh. U-turn | 11810 | 2 | 0 | 0 | 0 | 1 | m10 | 1 | 1 |
| Proh. U-turn, hill crest | 11840 | 2 | 1 | 0 | 0 | 0 | m10 | 1 | |

Appendix 2

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Prohibited turn | 11920 | 2 | 85 | 91 | 64 | 40 | m10 | 280 | |
| By-law, proh. U-turn | 80080 | 2 | 1 | 3 | 1 | 1 | m10 | 6 | |
| U-turn unsafe | 80015 | | 0 | 0 | 1 | 0 | m10 | 1 | |
| Prohibited turn | 80020 | 2 | 0 | 0 | 34 | 61 | m10 | 95 | |
| By-law, proh. Turn | 80110 | 2 | 57 | 66 | 47 | 12 | m10 | 182 | |
| " amber " | 11870 | 3 | 52 | 37 | 31 | 18 | m14 | 138 | 3 |
| Disobey amber light | 11921 | 3 | 0 | 0 | 0 | 3 | m14 | 3 | 1 |
| Disob. green arrow | 11900 | 3 | 1 | 1 | 2 | 0 | m15 | 4 | |
| Fail proc. at flash. green | 11905 | 3 | 2 | 1 | 1 | 1 | m15 | 5 | |
| Wrong-way,one-way street | 12110 | 3 | 17 | 17 | 10 | 14 | m18 | 58 | 2 |
| PXO viol. same side of rd. | 11640 | 2 | 2 | 3 | 1 | 1 | m9 | 7 | 1 |
| " " oth. " " " | 11650 | 2 | 1 | 2 | 2 | 1 | m9 | 6 | |
| " " | 11660 | 2 | 6 | 4 | 0 | 2 | m9 | 12 | |
| Pass at Ped. crossing | 11665 | 2 | 1 | 5 | 0 | 6 | m9 | 12 | |
| Fail stop for sch. bus. o/t | 12500 | 4 | 2 | 1 | 0 | 0 | m26 | 3 | |
| " " " " " meet | 12510 | 4 | 3 | 3 | 3 | 2 | m26 | 11 | |
| " " " " " o/t | 12511 | 6 | 0 | 0 | 1 | 0 | m26 | 1 | |

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**REVISED CATEGORY mm2**

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Disobey red light | 11860 | 3 | 160 | 150 | 122 | 79 | m13 | 511 | 46 |
| Disob. flashing red | 11880 | 3 | 5 | 1 | 2 | 6 | m13 | 14 | 4 |
| Disobey red light | 11925 | 3 | 0 | 0 | 0 | 19 | m13 | 19 | 2 |
| Dis. portable red light | 11926 | 3 | 0 | 0 | 1 | 0 | m13 | 1 | |
| Fail stop at r/r cross. | 12250 | 5 | 0 | 0 | 1 | 0 | m22 | 1 | |
| Crossing r/way barrier | 12260 | 3 | 1 | 1 | 1 | 0 | m22 | 3 | |

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**REVISED CATEGORY mm3**

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Unnec. slow driving | 11520 | 2 | 2 | 2 | 0 | 0 | m4 | 4 | 1 |
| Fail to stop for emer/veh. | 12200 | | 3 | 1 | 0 | 0 | m21 | 4 | |
| " obey sch. cr. stop sign | 12535 | | 0 | 1 | 0 | 0 | m21 | 1 | |
| Fail lower h'light beam app. | 12325 | 2 | 1 | 1 | 2 | 0 | m24 | 4 | 0 |
| Fail to rep. accident | 12710 | 3 | 11 | 13 | 13 | 9 | m29 | 46 | 36 |
| Crowding driver seat | 12240 | 3 | 1 | 2 | 3 | 3 | m41 | 9 | 1 |
| Radar dev in m/v | 10925 | | 0 | 1 | 0 | 2 | m44 | 3 | |
| No safe helmet, motor cy. | 11090 | | 0 | 5 | 3 | 0 | m45 | 8 | |
| Fail to signal to stop | 11780 | 2 | 0 | 0 | 1 | 0 | m46 | 1 | |
| Fail stop for pol. officer | 12785 | | 0 | 1 | 2 | 1 | m48 | 4 | |
| Crim neg. caus. death CCC | 70030 | | 0 | 0 | 1 | 0 | m31 | 1 | 1 |
| Dang. driving CCC | 70060 | | 0 | 0 | 0 | 1 | m32 | 1 | 0 |
| Danger. driving CCC | 70120 | | 2 | 4 | 1 | 3 | m34 | 10 | 6 |
| Careless driving | 11490 | 6 | 55 | 47 | 45 | 46 | m3 | 193 | 142 |

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**REVISED CATEGORY mm4**

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Unsafe move | 11750 | 2 | 33 | 33 | 35 | 25 | m11 | 126 | 75 |
| " " from parked pos. | 11760 | 2 | 6 | 11 | 11 | 9 | m11 | 37 | 26 |
| Imp. open., veh door | 12270 | 2 | 0 | 1 | 0 | 1 | m11 | 2 | |

Appendix 2

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Fail to share road | 11940 | 2 | 10 | 5 | 7 | 6 | m16 | 28 | 16 |
| Fail share when overtaken | 11960 | 2 | 1 | Ø | Ø | Ø | m16 | 1 | |
| " " " overtaking | 11970 | 2 | 2 | 1 | 1 | Ø | m16 | 4 | 3 |
| Fail to turn out to rt/lt | 11980 | 2 | Ø | 1 | Ø | Ø | m16 | 1 | |
| Improper passing | 12000 | 3 | Ø | 1 | Ø | Ø | m17 | 1 | |
| Imp. pass.- appr. traffic | 12010 | 3 | 3 | 1 | 2 | Ø | m17 | 6 | 1 |
| Imp. pass. - overt.traffic | 12020 | 3 | Ø | Ø | 1 | 1 | m17 | 2 | 1 |
| Driving left of center | 12040 | 3 | 4 | 7 | 2 | 2 | m17 | 15 | 1 |
| Dr. l. of cen. lev. cross. | 12045 | 3 | Ø | Ø | 1 | Ø | m17 | 1 | |
| Pass on right/off r'way | 12100 | 3 | 8 | 9 | 8 | 4 | m17 | 29 | 3 |
| Imp. pass. stpd. str.car | 12290 | 3 | 1 | 2 | 1 | Ø | m17 | 4 | |
| Disob. traffic sign | 11885 | 2 | Ø | Ø | Ø | 4 | m28 | 4 | |
| Disobey legal sign | 12610 | 2 | 10 | 17 | 10 | 11 | m28 | 48 | 1 |
| Fail st. sign or mk. int. | 11851 | | Ø | Ø | Ø | 1 | m28 | 1 | 1 |
| Disobey sign re- tunnels | 12620 | | Ø | Ø | Ø | 1 | m28 | 1 | |
| By-law, disob. sign | 80160 | | Ø | 1 | 4 | 6 | m28 | 11 | |

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**REVISED CATEGORY mm5**

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Fail remain at scene accid. | 12730 | 7 | 7 | 7 | 4 | 9 | m30 | 27 | 17 |
| Fail/ref. breath test CCC | 70185 | | 1 | 2 | 3 | 2 | m36 | 8 | |
| Fail or ref. breath sam.CCC | 70212 | | 3 | 8 | 6 | 6 | m37 | 23 | 5 |
| Fail rem at accid. CCC | 70090 | | 3 | 3 | 2 | 10 | m33 | 18 | 11 |
| Driving with >80 mgs.alcoh. | 70214 | | 63 | 62 | 46 | 66 | m38 | 237 | 37 |
| Impaired driving C.C.C. | 70174 | | 40 | 56 | 46 | 42 | m35 | 184 | 41 |

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**REVISED CATEGORY mm6**

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Drive on closed h'way | 11556 | 3 | 1 | 1 | Ø | 2 | m19 | 4 | |
| Imp. dr. multi-ln. h'way | 11930 | | 1 | 1 | 1 | Ø | m19 | 3 | |
| Fail obey paved shld. signs | 12105 | | Ø | 4 | 1 | 3 | m19 | 8 | |
| Imp. driving, div. h'way | 12120 | 3 | 18 | 13 | 21 | 11 | m19 | 63 | 31 |
| Imp. use cen. ln.,3-lane r. | 12130 | 3 | Ø | Ø | Ø | 1 | m19 | 1 | |
| Disobey off.signs,div.h'way | 12140 | 3 | 14 | 18 | 12 | 7 | m19 | 51 | |
| Imp. driving,div.h'way | 12150 | 3 | 1 | 2 | 4 | 2 | m19 | 9 | 1 |
| Dr. m/v on sidewalk | 80016 | | Ø | Ø | Ø | 2 | m19 | 2 | |
| Dr. in des. bus lane | 80012 | | Ø | Ø | 2 | 3 | m19 | 5 | |
| Enter proh. h'way/r'dway | 80022 | | Ø | Ø | 2 | 3 | m19 | 5 | |
| F.T.C. | 12170 | 4 | 1 | 1 | 1 | Ø | m20 | 3 | 2 |
| F.T.C., motor vehicle | 12180 | 4 | 41 | 35 | 44 | 54 | m20 | 174 | 133 |
| Imp. parking | 12360 | | Ø | Ø | 1 | 1 | m25 | 2 | |
| Imp. parking | 12380 | | Ø | 1 | Ø | Ø | m25 | 1 | |
| Imp. park., Interf. w.traf | 12430 | | Ø | 3 | 1 | 1 | m25 | 5 | |
| Improper parking | 90510 | | Ø | Ø | Ø | 2 | m25 | 2 | |
| F.T.C., commer. m/v | 12190 | 4 | 1 | 1 | 1 | 1 | m47 | 4 | 1 |
| Dr. comm. veh. lt. lane | 80010 | | Ø | Ø | 1 | Ø | m47 | 1 | |
| Fail/imp. use of Seat Belt | 11097 | | 228 | 227 | 250 | 126 | m1 | 831 | 22 |
| Fail ens. passen. s. belt | 11099 | | Ø | 1 | 10 | 13 | m1 | 24 | 2 |

Appendix 2

REVISED CATEGORY mm7

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Speeding -- km in --km zn. | 11355 | 6 | 2269 | 2212 | 2127 | 1949 | m2 8557 | 4 |
| Speeding | 11485 | | Ø | Ø | 1 | 1 | m2 2 | |

# APPENDIX 3

## Model Weights for Alternate Demerit Point Schemes

Appendix 3

Regression Run A1: Age, sex as dummies, no accidents

| Description of variable | Estimated Coefficient | Standard Error |
| --- | --- | --- |
| Intercept (Male, Age < 21) | 0.1839 | 0.00284 |
| Dummy variable for age 21-25 | -0.03752 | 0.002832 |
| Dummy variable for age 26-30 | -0.0564 | 0.002894 |
| Dummy variable for age 31-35 | -0.0609 | 0.003025 |
| Dummy variable for age 36-40 | -0.05246 | 0.003499 |
| Dummy variable for age 41-50 | -0.06007 | 0.003491 |
| Dummy variable for age 51-60 | -0.05909 | 0.004776 |
| Dummy variable for age > 60 | -0.06138 | 0.006789 |
| Dummy variable for female | -0.06661 | 0.001721 |
| mm1: Fail to yield, imp. turns, PXO, amber violations, etc | 0.02736 | 0.001646 |
| mm2: Disobey red lights; rail crossing violations. | 0.045535 | 0.002791 |
| mm3: Fail report accid.; Careless driving; Dang. driving;Crim. neg. caus. death | 0.048755 | 0.004567 |
| mm4: Unsafe move;imp. o'taking; Disobey signs | 0.059365 | 0.003723 |
| mm5: Fail to remain; breath test; alcohol; impairment. | 0.068515 | 0.015328 |
| mm6: Seat belt; F.T.C.; parking; divided h'way offences. | 0.03421 | 0.001961 |
| nn1: Minor neglect: no drivers license; permits; insurance, address change | 0.031975 | 0.009674 |
| nn2: Neglect: D/Lic. suspended or not produced; plates, insurance. | 0.03312 | 0.003617 |
| vv1: Minor vehicle neglect: lamps windows obstructed, etc. | 0.051595 | 0.006479 |
| vv2: Vehicle neglect: Unsafe veh., brakes, tires | 0.08548 | 0.009013 |
| vv3: Truck weight offences. | 0.187235 | 0.025898 |
| vv4: Truck dimension offences. | 0.11554 | 0.011842 |
| ee1: Environmental offences: noise, fumes. | 0.091265 | 0.008340 |
| mm7: Speeding offences | 0.02902 | 0.000840 |

Regression Run A2: Age, sex as dummies, tot. accs.

| Description of variable | Estimated Coefficient | Standard Error |
|---|---|---|
| Intercept (Male, Age < 21) | 0.1763 | 0.002876 |
| Dummy variable for age 21-25 | -0.03856 | 0.002852 |
| Dummy variable for age 26-30 | -0.0565 | 0.002913 |
| Dummy variable for age 31-35 | -0.06006 | 0.003044 |
| Dummy variable for age 36-40 | -0.05202 | 0.003516 |
| Dummy variable for age 41-50 | -0.06013 | 0.00351 |
| Dummy variable for age 51-60 | -0.05744 | 0.004832 |
| Dummy variable for age > 60 | -0.06156 | 0.007068 |
| Dummy variable for female | -0.06122 | 0.001735 |
| mm1: Fail to yield, imp. turns, PXO, amber violations, etc | 0.02696 | 0.001753 |
| mm2: Disobey red lights; rail crossing violations. | 0.042125 | 0.002916 |
| mm3: Fail report accid.; Careless driving; Dang. driving;Crim. neg. caus. death | 0.02330 | 0.008613 |
| mm4: Unsafe move;imp. o'taking; Disobey signs | 0.06359 | 0.004959 |
| mm5: Fail to remain; breath test; alcohol; impairment. | 0.2444 | 0.054575 |
| mm6: Seat belt; F.T.C.; parking; divided h'way offences. | 0.2444 | 0.054575 |
| nn1: Minor neglect: no drivers license; permits; insurance, address change | 0.02624 | 0.010463 |
| nn2: Neglect: D/Lic. suspended or not produced; plates, insurance. | 0.03366 | 0.003708 |
| vv1: Minor vehicle neglect: lamps windows obstructed, etc. | 0.03366 | 0.003708 |
| vv2: Vehicle neglect: Unsafe veh., brakes, tires | 0.08673 | 0.009296 |
| vv3: Insecure load. | 0.15922 | 0.027210 |
| vv4: Weight and dimension offences. | 0.11074 | 0.011895 |
| ee1: Environmental offences: noise, fumes. | 0.08748 | 0.008334 |
| mm7: Speeding offences | 0.026515 | 0.000866 |
| Total accidents in period 1 | 0.05831 | 0.001580 |

Appendix 3

**Regression Run A3: Age, sex as dummies, fault accs.**

| Description of variable | Estimated Coefficient | Standard Error |
|---|---|---|
| Intercept (Male, Age < 21) | 0.1811 | 0.002923 |
| Dummy variable for age 21-25 | -0.03879 | 0.002905 |
| Dummy variable for age 26-30 | -0.05755 | 0.002968 |
| Dummy variable for age 31-35 | -0.06119 | 0.003101 |
| Dummy variable for age 36-40 | -0.05309 | 0.003581 |
| Dummy variable for age 41-50 | -0.06141 | 0.003576 |
| Dummy variable for age 51-60 | -0.05906 | 0.004922 |
| Dummy variable for age > 60 | -0.06341 | 0.007197 |
| Dummy variable for female | -0.06346 | 0.001764 |
| mm1: Fail to yield, imp. turns, PXO, amber violations, etc | 0.02833 | 0.001937 |
| mm2: Disobey red lights; rail crossing violations. | 0.044105 | 0.003221 |
| mm3: Fail report accid.; Careless driving; Dang. driving;Crim. neg. caus. death | 0.025255 | 0.009526 |
| mm4: Unsafe move;imp. o'taking; Disobey signs | 0.065445 | 0.005480 |
| mm5: Fail to remain; breath test; alcohol; impairment. | 0.2462 | 0.061209 |
| mm6: Seat belt; F.T.C.; parking; divided h'way offences. | 0.03359 | 0.002356 |
| nn1: Minor neglect: no drivers license; permits; insurance, address change | 0.02664 | 0.011584 |
| nn2: Neglect: D/Lic. suspended or not produced; plates, insurance. | 0.03417 | 0.004099 |
| vv1: Minor vehicle neglect: lamps windows obstructed, etc. | 0.05188 | 0.007244 |
| vv2: Vehicle neglect: Unsafe veh., brakes, tires | 0.08958 | 0.010293 |
| vv3: Insecure load | 0.166275 | 0.029826 |
| vv4: Weight & dimension offences. | 0.114335 | 0.013051 |
| ee1: Environmental offences: noise, fumes. | 0.089395 | 0.009204 |
| mm7: Speeding offences | 0.027835 | 0.000957 |
| Total at fault accidents in period 1 | 0.056635 | 0.002495 |

Appendix 3

**Regression Run A4: Age/sex as dummies, fault, not at fault accs.**

| Description of variable | Estimated Coefficient | Standard Error |
|---|---|---|
| Intercept (Male, Age < 21) | 0.1763 | 0.002876 |
| Dummy variable for age 21-25 | -0.03856 | 0.002852 |
| Dummy variable for age 26-30 | -0.0565 | 0.002913 |
| Dummy variable for age 31-35 | -0.06006 | 0.003044 |
| Dummy variable for age 36-40 | -0.05202 | 0.003516 |
| Dummy variable for age 41-50 | -0.06013 | 0.00351 |
| Dummy variable for age 51-60 | -0.05744 | 0.004832 |
| Dummy variable for age > 60 | -0.06156 | 0.007068 |
| Dummy variable for female | -0.06122 | 0.001735 |
| mm1: Fail to yield, imp. turns, PXO, amber violations, etc | 0.02697 | 0.001900 |
| mm2: Disobey red lights; rail crossing violations. | 0.04211 | 0.003158 |
| mm3: Fail report accid.; Careless driving; Dang. driving;Crim. neg. caus. death | 0.02344 | 0.009338 |
| mm4: Unsafe move;imp. o'taking; Disobey signs | 0.06367 | 0.005372 |
| mm5: Fail to remain; breath test; alcohol; impairment. | 0.2443 | 0.060010 |
| mm6: Seat belt; F.T.C.; parking; divided h'way offences. | 0.03222 | 0.002310 |
| nn1: Minor neglect: no drivers license; permits; insurance, address change | 0.02638 | 0.011354 |
| nn2: Neglect: D/Lic. suspended or not produced; plates, insurance. | 0.03374 | 0.004018 |
| vv1: Minor vehicle neglect: lamps windows obstructed, etc. | 0.04954 | 0.007103 |
| vv2: Vehicle neglect: Unsafe veh., brakes, tires | 0.08675 | 0.010091 |
| vv3: Insecure load | 0.15859 | 0.029246 |
| vv4: Weight & dimension offences. | 0.1109 | 0.012793 |
| ee1: Environmental offences: noise, fumes. | 0.08756 | 0.009020 |
| mm7: Speeding offences | 0.02650 | 0.000939 |
| Total at fault accidents in period 1 | 0.05451 | 0.002446 |
| Total driving properly accidents, period 1 | 0.06226 | 0.002484 |

Appendix 3

**Regression Run B1: No Age/sex variables, no accs.**

| Description of variable | Estimated Coefficient | Standard Error |
|---|---|---|
| Intercept | 0.1083 | 0.001486 |
| mm1: Fail to yield, imp. turns, PXO, amber violations, etc | 0.03224 | 0.001790 |
| mm2: Disobey red lights; rail crossing violations. | 0.05341 | 0.003035 |
| mm3: Fail report accid.; Careless driving; Dang. driving;Crim. neg. caus. death | 0.06617 | 0.004958 |
| mm4: Unsafe move;imp. o'taking; Disobey signs | 0.06722 | 0.004054 |
| mm5: Fail to remain; breath test; alcohol; impairment. | 0.079245 | 0.016679 |
| mm6: Seat belt; F.T.C.; parking; divided h'way offences. | 0.043205 | 0.002128 |
| nn1: Minor neglect: no drivers license; permits; insurance, address change | 0.043055 | 0.010544 |
| nn2: Neglect: D/Lic. suspended or not produced; plates, insurance. | 0.04907 | 0.003926 |
| vv1: Minor vehicle neglect: lamps windows obstructed, etc. | 0.06633 | 0.007045 |
| vv2: Vehicle neglect: Unsafe veh., brakes, tires | 0.10202 | 0.009826 |
| vv3: Insecure load | 0.2004 | 0.027991 |
| vv4: Weight & dimension offences. | 0.12488 | 0.012789 |
| ee1: Environmental offences: noise, fumes. | 0.1207 | 0.009048 |
| mm7: Speeding offences | 0.03416 | 0.000907 |

**Regression Run B2: No Age/sex variables, total accs.**

| Description of variable | Estimated Coefficient | Standard Error |
|---|---|---|
| Intercept | 0.10335 | 0.001520 |
| mm1: Fail to yield, imp. turns, PXO, amber violations, etc | 0.03148 | 0.001886 |
| mm2: Disobey red lights; rail crossing violations. | 0.04925 | 0.003138 |
| mm3: Fail report accid.; Careless driving; Dang. driving;Crim. neg. caus. death | 0.041585 | 0.009278 |
| mm4: Unsafe move;imp. o'taking; Disobey signs | 0.072585 | 0.005341 |
| mm5: Fail to remain; breath test; alcohol; impairment. | 0.25755 | 0.059830 |
| mm6: Seat belt; F.T.C.; parking; divided h'way offences. | 0.03992 | 0.002290 |
| nn1: Minor neglect: no drivers license; permits; insurance, address change | 0.035915 | 0.011297 |
| nn2: Neglect: D/Lic. suspended or not produced; plates, insurance. | 0.04807 | 0.003981 |
| vv1: Minor vehicle neglect: lamps windows obstructed, etc. | 0.062545 | 0.007060 |
| vv2: Vehicle neglect: Unsafe veh., brakes, tires | 0.101415 | 0.010035 |
| vv3: Insecure load | 0.169635 | 0.029073 |
| vv4: Weight & dimension offences. | 0.11832 | 0.012712 |
| ee1: Environmental offences: noise, fumes. | 0.114985 | 0.008946 |
| mm7: Speeding offences | 0.03063 | 0.000927 |
| Total accidents in period 1 | 0.065045 | 0.001696 |

Appendix 3

**Regression Run B3: No Age/sex variables, fault accs.**

| Description of variable | Estimated Coefficient | Standard Error |
|---|---|---|
| Intercept | 0.10695 | 0.001520 |
| mm1: Fail to yield, imp. turns, PXO, amber violations, etc | 0.03314 | 0.001893 |
| mm2: Disobey red lights; rail crossing violations. | 0.051685 | 0.003150 |
| mm3: Fail report accid.; Careless driving; Dang. driving;Crim. neg. caus. death | 0.04427 | 0.009317 |
| mm4: Unsafe move;imp. o'taking; Disobey signs | 0.074925 | 0.005363 |
| mm5: Fail to remain; breath test; alcohol; impairment. | 0.2602 | 0.059893 |
| mm6: Seat belt; F.T.C.; parking; divided h'way offences. | 0.04174 | 0.002298 |
| nn1: Minor neglect: no drivers license; permits; insurance, address change | 0.036755 | 0.011343 |
| nn2: Neglect: D/Lic. suspended or not produced; plates, insurance. | 0.04918 | 0.003997 |
| vv1: Minor vehicle neglect: lamps windows obstructed, etc. | 0.06561 | 0.007088 |
| vv2: Vehicle neglect: Unsafe veh., brakes, tires | 0.10512 | 0.010074 |
| vv3: Insecure load | 0.178085 | 0.029239 |
| vv4: Weight & dimension offences. | 0.122515 | 0.012786 |
| ee1: Environmental offences: noise, fumes. | 0.118 | 0.008981 |
| mm7: Speeding offences | 0.03226 | 0.000929 |
| Total at fault accidents in period 1 | 0.06507 | 0.002433 |

Appendix 3

**Regression Run B4: No Age/sex var., fau.,n/f. accs.**

| Description of variable | Estimated Coefficient | Standard Error |
|---|---|---|
| Intercept | 0.10335 | 0.001494 |
| mm1: Fail to yield, imp. turns, PXO, amber violations, etc | 0.031495 | 0.001855 |
| mm2: Disobey red lights; rail crossing violations. | 0.049245 | 0.003085 |
| mm3: Fail report accid.; Careless driving; Dang. driving;Crim. neg. caus. death | 0.0417 | 0.009119 |
| mm4: Unsafe move;imp. o'taking; Disobey signs | 0.07265 | 0.005251 |
| mm5: Fail to remain; breath test; alcohol; impairment. | 0.25755 | 0.058638 |
| mm6: Seat belt; F.T.C.; parking; divided h'way offences. | 0.039935 | 0.002251 |
| nn1: Minor neglect: no drivers license; permits; insurance, address change | 0.03602 | 0.011103 |
| nn2: Neglect: D/Lic. suspended or not produced; plates, insurance. | 0.048135 | 0.003913 |
| vv1: Minor vehicle neglect: lamps windows obstructed, etc. | 0.06255 | 0.006942 |
| vv2: Vehicle neglect: Unsafe veh., brakes, tires | 0.101415 | 0.009862 |
| vv3: Insecure load | 0.16913 | 0.028628 |
| vv4: Weight & dimension offences. | 0.11844 | 0.012517 |
| ee1: Environmental offences: noise, fumes. | 0.115085 | 0.008794 |
| mm7: Speeding offences | 0.030625 | 0.000911 |
| Total at fault accidents in period 1 | 0.06248 | 0.002384 |
| Total driving properly accidents, period 1 | 0.06775 | 0.002427 |

**Regression Run C1: Age,sex; total cons., no accs.**

| Description of variable | Estimated Coefficient | Standard Error |
|---|---|---|
| Intercept (Male, Age < 21) | 0.1839 | 0.00284 |
| Dummy variable for age 21-25 | -0.03752 | 0.002832 |
| Dummy variable for age 26-30 | -0.0564 | 0.002894 |
| Dummy variable for age 31-35 | -0.0609 | 0.003025 |
| Dummy variable for age 36-40 | -0.05246 | 0.003499 |
| Dummy variable for age 41-50 | -0.06007 | 0.003491 |
| Dummy variable for age 51-60 | -0.05909 | 0.004776 |
| Dummy variable for age > 60 | -0.06138 | 0.006789 |
| Dummy variable for female | -0.06661 | 0.001721 |
| Total convictions, period 1 | 0.03212 | 0.000812 |

Appendix 3

Regression Run C2: Age,sex; total cons., total accs.

| Description of variable | Estimated Coefficient | Standard Error |
|---|---|---|
| Intercept (Male, Age < 21) | 0.1763 | 0.002876 |
| Dummy variable for age 21-25 | -0.03856 | 0.002852 |
| Dummy variable for age 26-30 | -0.0565 | 0.002913 |
| Dummy variable for age 31-35 | -0.06006 | 0.003044 |
| Dummy variable for age 36-40 | -0.05202 | 0.003516 |
| Dummy variable for age 41-50 | -0.06013 | 0.00351 |
| Dummy variable for age 51-60 | -0.05744 | 0.004832 |
| Dummy variable for age > 60 | -0.06156 | 0.007068 |
| Dummy variable for female | -0.06122 | 0.001735 |
| Total convictions, period 1 | 0.02951 | 0.000827 |
| Total Accidents, period 1 | 0.05902 | 0.001674 |

**Regression Run C3: Age,sex; total cons., fault accs.**

| Description of variable | Estimated Coefficient | Standard Error |
|---|---|---|
| Intercept (Male, Age < 21) | 0.1811 | 0.002923 |
| Dummy variable for age 21-25 | -0.03879 | 0.002905 |
| Dummy variable for age 26-30 | -0.05755 | 0.002968 |
| Dummy variable for age 31-35 | -0.06119 | 0.003101 |
| Dummy variable for age 36-40 | -0.05309 | 0.003581 |
| Dummy variable for age 41-50 | -0.06141 | 0.003576 |
| Dummy variable for age 51-60 | -0.05906 | 0.004922 |
| Dummy variable for age > 60 | -0.06341 | 0.007197 |
| Dummy variable for female | -0.06346 | 0.001764 |
| Total convictions, period 1 | 0.03102 | 0.000840 |
| At Fault Accidents, period 1 | 0.05743 | 0.002434 |

Appendix 3

Regression Run C4: Age,sex; tot. cons., f.,n/f. accs.

| Description of variable | Estimated Coefficient | Standard Error |
|---|---|---|
| Intercept (Male, Age < 21) | 0.1763 | 0.002876 |
| Dummy variable for age 21-25 | -0.03856 | 0.002852 |
| Dummy variable for age 26-30 | -0.0565 | 0.002913 |
| Dummy variable for age 31-35 | -0.06006 | 0.003044 |
| Dummy variable for age 36-40 | -0.05202 | 0.003516 |
| Dummy variable for age 41-50 | -0.06013 | 0.00351 |
| Dummy variable for age 51-60 | -0.05744 | 0.004832 |
| Dummy variable for age > 60 | -0.06156 | 0.007068 |
| Dummy variable for female | -0.06122 | 0.001735 |
| Total convictions, period 1 | 0.02951 | 0.000827 |
| At Fault Accidents, period 1 | 0.05526 | 0.002388 |
| Driving properly accidents, period 1 | 0.06289 | 0.002426 |

Appendix 3

Regression Run D1: No age,sex; tot. cons., no accs.

| Description of variable | Estimated Coefficient | Standard Error |
|---|---|---|
| Intercept | 0.1073 | 0.001424 |
| Total convictions, period 1 | 0.03891 | 0.000773 |

Regression Run D2: No age,sex; tot. cons., tot. accs.

| Description of variable | Estimated Coefficient | Standard Error |
|---|---|---|
| Intercept | 0.1019 | 0.001431 |
| Total convictions, period 1 | 0.03518 | 0.000785 |
| Total Accidents, period 1 | 0.06618 | 0.001604 |

Appendix 3

Regression Run D3: No age,sex; tot. cons., fau. accs.

| Description of variable | Estimated Coefficient | Standard Error |
|---|---|---|
| Intercept | 0.1053 | 0.001454 |
| Total convictions, period 1 | 0.03705 | 0.000798 |
| At fault Accidents, period 1 | 0.06644 | 0.002338 |

Regression Run D4: No age,sex; tot.cons., f.n/f. accs.

| Description of variable | Estimated Coefficient | Standard Error |
|---|---|---|
| Intercept | 0.1019 | 0.001431 |
| Total convictions, period 1 | 0.03518 | 0.000785 |
| At fault Accidents, period 1 | 0.06378 | 0.002291 |
| Driving properly accidents, period 1 | 0.06862 | 0.002334 |

APPENDIX 4

# Theoretical Framework

## Theorectical Framework

Each driver has an expected number of accidents for 1983-1984. For driver i this will be denoted by $m_i$. Consider a reference population of drivers identical in gender, age-group, and also in their 1981-1982 count of convictions and accidents. The average of their m's is E{m}. Since not all the m's in the reference population are the same, there is also a variance of m's, VAR{m}.

We estimate E{m} by

$$E\{m\} = a_1 + a_g + a_s + b_1x_1 + b_2x_2 + \dots \qquad (1)$$

where

$a_1$ is a parameter for the "Base Driver" (who is a male in the 17-21 age group).

$a_g$ is a parameter, g = 2,3,...8, depending on the age group as shown below

| | |
|---|---|
| 2 | 21-25 years old in 1982 |
| 3 | 26-30 " " " " |
| 4 | 31-35 " " " " |
| 5 | 36-40 " " " " |
| 6 | 41-50 " " " " |
| 7 | 51-60 " " " " |
| 8 | > 60 " " " " |

$a_s$ is a parameter for "female" and $b_1$, $b_2$ .. are the "weights or "parameters" for variables $x_1$, $x_2$ etc., which are the numbers of convictions or accidents of a given type during 1981-1982.

We estimate the variance of the m's by

$$VAR\{m\} = [E\{m\}]^2/k \qquad (2)$$

where k is a parameter.

### A4.2 Estimation of Parameters

We have estimated the parameters of equation (1) by a software well suited for accident counts. It facilitates the appropriate representation of accident counts by the negative binomial distribution and yields maximum likelihood estimates for the parameters. (Baker, R.J. and Nelder, J.A., The GLIM system. Generalized Linear Interactive Modelling, 1978.)

The parameter k in equation (2) has also been estimated by maximum likelihood methods. A special program had to be written for this purpose.

## A4.3 Estimation of E{m} and VAR{m} from Accident Counts

It can be shown that if for every driver the accident occurrence obeys the Poisson Probability Law, then, for a group of drivers,

$E\{m\} = x =$ sample mean of accident counts

$VAR\{m\} = s^2 - x$ where $s^2$ is the sample variance of accident counts.

## A4.4 The "Gamma Assumption"

Much of the analysis in section 4 rests on the assumption that the distribution of m's (accident potential) in the population of the Ontario drivers can be represented by a Gamma probability distribution function. As noted in the main text in section 4.4 we cannot be sure this assumption is a valid one until we check whether the accident counts which are observed support the "Gamma Assumption".

In tables A4.1 to A4.9 we check whether the number of drivers observed to have 0,1,2,... accidents can be well reproduced if one uses only x, $s^2$, and the Poisson and Gamma assumptions. Thus, for example, there were 6923 males, 17-20 years old, who during 1981-1984 had 1 accident (see Table A4.1). During the same period of time for males who were 17-20 years old, the sample mean was 0.463 accidents and the sample standard deviation was 0.718 accidents. Using these two sample statistics, we should expect 6867 drivers to have 1 accident if the "Gamma Assumption" was correct (Table A4.1). What has been observed and what is expected if the Gamma Assumption is correct seems to correspond. In fact, all pairs of numbers in all tables display good correspondence.

In tables A4.1 - A4.9 the Gamma assumption was tested "weakly". We used two numbers ($x,s^2$) to generate 5 to 9 other numbers and showed that these matched well what has been observed. We now proceed with a stronger test.

In tables A4.10 to A4.23 we examine 14 two period tables. Thus, for example, in Table A4.10 we show that 3214 male drivers, 17-20 years of age, had 0 accidents in 1981-1982 and 1 accident during 1983-1984. Now, using only $x,s^2$ for 1981-1982 and x for 1983-1984, we use the Gamma assumption to estimate what would be the expected number of such drivers - 3232.3. Once again, the correspondence in all 15 tables is impressive.

We conclude that the information we have about accident counts for Ontario drivers does not contradict the appropriateness of making use of the Gamma Assumption.

ABLE A4.1: ACCIDENT DISTRIBUTION FOR 17-20 YEAR OLDS

| No. of accs 1981-84 (x) | MALES (x=.463,s=.718) Drivers with x accs. Observed | Estimated | FEMALES (x=.192,s=.452) Drivers with x accs. Observed | Estimated |
|---|---|---|---|---|
| 0 | 16507 | 16537 | 16966 | 16977 |
| 1 | 6923 | 6867 | 3092 | 3060 |
| 2 | 1775 | 1782 | 339 | 369 |
| 3 | 343 | 370 | 45 | 37 |
| 4 | 75 | 67 | 5 | 3 |
| 5 | 13 | 11 | | |
| 6 | 0 | 2 | | |
| All | 25636 | | 20447 | |

TABLE A4.2: ACCIDENT DISTRIBUTION FOR 21-25 YEAR OLDS

| No. of accs 1981-84 (x) | MALES (x=.379,s=.664) Drivers with x accs. Observed | Estimated | FEMALES (x=.164,s=.423) Drivers with x accs. Observed | Estimated |
|---|---|---|---|---|
| 0 | 45054 | 45224 | 50331 | 50359 |
| 1 | 15182 | 14778 | 7623 | 7557 |
| 2 | 3203 | 3441 | 855 | 889 |
| 3 | 662 | 693 | 84 | 95 |
| 4 | 154 | 129 | 11 | 10 |
| 5 | 28 | 23 | 7 | 1 |
| 6 | 5 | 4 | | |
| 7 | 4 | 1 | | |
| All | 64292 | | 58911 | |

**TABLE A4.3: ACCIDENT DISTRIBUTION FOR 26-3Ø YEAR OLDS**

| | MALES (x=.3Ø6,s=.6Ø9) | | FEMALES (x=.132,s=.38Ø) | |
|---|---|---|---|---|
| No. of accs 1981-84 (x) | Drivers with x accs. Observed | Estimated | Drivers with x accs. Observed | Estimated |
| Ø | 49857 | 5ØØ16 | 57888 | 579Ø2 |
| 1 | 12961 | 126Ø7 | 6968 | 6946 |
| 2 | 2528 | 27ØØ | 734 | 726 |
| 3 | 493 | 544 | 52 | 72 |
| 4 | 12Ø | 1Ø6 | 7 | 7 |
| 5 | 23 | 2Ø | 4 | 1 |
| 6 | 12 | 4 | Ø | Ø |
| 7 | 1 | 1 | 1 | Ø |
| 8 | 2 | Ø | | |
| 9 | 1 | Ø | | |
| All | 65998 | | 65654 | |

**TABLE A4.4: ACCIDENT DISTRIBUTION FOR 31-35 YEAR OLDS**

| | MALES (x=.289,s=.586) | | FEMALES (x=.132,s=.382) | |
|---|---|---|---|---|
| No. of accs 1981-84 (x) | Drivers with x accs. Observed | Estimated | Drivers with x accs. Observed | Estimated |
| Ø | 39864 | 39993 | 5Ø866 | 5Ø891 |
| 1 | 1ØØØ5 | 9738 | 6177 | 61Ø8 |
| 2 | 1861 | 1952 | 589 | 648 |
| 3 | 291 | 363 | 78 | 66 |
| 4 | 74 | 65 | 9 | 7 |
| 5 | 16 | 11 | Ø | 1 |
| 6 | 7 | 2 | 1 | Ø |
| 7 | 4 | Ø | | |
| 8 | 2 | Ø | | |
| All | 52124 | | 5772Ø | |

TABLE A4.5: ACCIDENT DISTRIBUTION FOR 36-40 YEAR OLDS

| No. of accs 1981-84 (x) | MALES (x=.286, s=.594) Drivers with x accs. Observed | Estimated | FEMALES (x=.137, s=.390) Drivers with x accs. Observed | Estimated |
|---|---|---|---|---|
| 0 | 20440 | 20502 | 29255 | 29254 |
| 1 | 4884 | 4744 | 3602 | 3609 |
| 2 | 927 | 1000 | 416 | 402 |
| 3 | 192 | 204 | 32 | 43 |
| 4 | 43 | 41 | 7 | 5 |
| 5 | 9 | 8 | 1 | 1 |
| 6 | 1 | 2 | | |
| 7 | 5 | 0 | | |
| All | 26501 | | 33313 | |

TABLE A4.6: ACCIDENT DISTRIBUTION FOR 41-50 YEAR OLDS

| No. of accs 1981-84 (x) | MALES (x=.261, s=.565) Drivers with x accs. Observed | Estimated | FEMALES (x=.122, s=.366) Drivers with x accs. Observed | Estimated |
|---|---|---|---|---|
| 0 | 24587 | 24665 | 31084 | 31094 |
| 1 | 5420 | 5256 | 3460 | 3435 |
| 2 | 970 | 1041 | 336 | 348 |
| 3 | 186 | 201 | 27 | 34 |
| 4 | 28 | 38 | 8 | 3 |
| 5 | 10 | 7 | 1 | 0 |
| 6 | 3 | 1 | | |
| 7 | 5 | 0 | | |
| 8 | 1 | 0 | | |
| All | 31210 | | 34916 | |

**TABLE A4.7: ACCIDENT DISTRIBUTION FOR 51-60 YEAR OLDS**

| | MALES (x=.229, s=.518) | | FEMALES (x=.108, s=.350) | |
|---|---|---|---|---|
| No. of accs 1981-84 (x) | Drivers with x accs. Observed | Estimated | Drivers with x accs. Observed | Estimated |
| 0 | 12119 | 12113 | 14873 | 14864 |
| 1 | 2361 | 2375 | 1387 | 1410 |
| 2 | 413 | 406 | 170 | 152 |
| 3 | 68 | 66 | 16 | 17 |
| 4 | 10 | 10 | 0 | 2 |
| 5 | 1 | 2 | | |
| All | 14972 | | 16446 | |

**TABLE A4.8: ACCIDENT DISTRIBUTION FOR > 60-YEAR OLDS**

| | MALES (x=.222, s=.521) | | FEMALES (x=.117, s=.350) | |
|---|---|---|---|---|
| No. of accs 1981-84 (x) | Drivers with x accs. Observed | Estimated | Drivers with x accs. Observed | Estimated |
| 0 | 6456 | 6469 | 7112 | 7111 |
| 1 | 1199 | 1173 | 788 | 792 |
| 2 | 197 | 213 | 66 | 63 |
| 3 | 41 | 39 | 4 | 4 |
| 4 | 5 | 7 | | |
| 5 | 4 | 1 | | |
| All | 7902 | | 7970 | |

TABLE A4.9: ACCIDENT DISTRIBUTION FOR ALL DRIVERS

| | MALES (x=.320, s=.618) | | FEMALES (x=.140, s=.393) | |
|---|---|---|---|---|
| No. of accs | Drivers with x accs. | | Drivers with x accs. | |
| 1981-84 (x) | Observed | Estimated | Observed | Estimated |
| 0 | 214884 | 215424 | 258375 | 258450 |
| 1 | 58935 | 57736 | 33097 | 32924 |
| 2 | 11874 | 12441 | 3505 | 3592 |
| 3 | 2276 | 2463 | 338 | 370 |
| 4 | 509 | 466 | 47 | 37 |
| 5 | 104 | 86 | 13 | 4 |
| 6 | 28 | 16 | 1 | 0 |
| 7 | 19 | 3 | 1 | 0 |
| 8 | 5 | 1 | | |
| 9 | 1 | 0 | | |
| All | 288635 | | 295377 | |

TABLE A4.10: 2-PERIOD ACCIDENT FREQUENCIES FOR MALES AGED 17-20 YEARS
(Period 1: Mean=0.2461, Var(x)=0.2605; Period 2: Mean=0.2173)

| Per. 1 Accs. | Observed and estimated no. of drivers with period 2 accident counts = 0 | | 1 | | 2 | | 3 | | 4 | | 5 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 16507 | 16519.8 | 3214 | 3232.3 | 422 | 391.6 | 37 | 37.7 | 5 | 3.2 | 0 | 0.2 |
| 1 | 3709 | 3660.5 | 840 | 886.9 | 122 | 128.1 | 15 | 14.3 | 3 | 1.4 | 0 | 0.1 |
| 2 | 513 | 502.2 | 125 | 145.1 | 31 | 24.3 | 6 | 3.1 | 0 | 0.3 | 0 | 0.0 |
| 3 | 59 | 54.8 | 19 | 18.4 | 2 | 3.5 | 0 | 0.5 | 0 | 0.1 | 0 | 0.0 |
| 4 | 5 | 5.2 | 1 | 2.0 | 0 | 0.4 | 0 | 0.1 | 0 | 0.0 | 0 | 0.0 |
| 5 | 1 | 0.5 | 0 | 0.2 | 0 | 0.1 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 |

TABLE A4.11: 2-PERIOD ACCIDENT FREQUENCIES FOR FEMALES AGED 17-20 YEARS
(Period 1: Mean=0.1057, Var(x)=0.1085; Period 2: Mean=0.0886)

| Per. 1 Accs. | Observed and estimated no. of drivers with period 2 accident counts = 0 | | 1 | | 2 | | 3 | | 4 | | 5 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 16966 | 16951.9 | 1382 | 1394.9 | 70 | 71.9 | 3 | 3.0 | 0 | 0.1 | 0 | 0.0 |
| 1 | 1710 | 1708.9 | 173 | 176.1 | 15 | 10.9 | 1 | 0.5 | 0 | 0.0 | 0 | 0.0 |
| 2 | 96 | 107.9 | 20 | 13.4 | 3 | 1.0 | 0 | 0.1 | 0 | 0.0 | 0 | 0.0 |
| 3 | 7 | 5.5 | 1 | 0.8 | 0 | 0.1 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 |
| 4 | 0 | 0.2 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 |
| 5 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 |

TABLE A4.12: 2-PERIOD ACCIDENT FREQUENCIES FOR MALES AGED 21-25 YEARS
(Period 1: Mean=Ø.2Ø49, Var(x)=Ø.2231; Period 2: Mean=Ø.1746)

| Per. 1 Accs. | Observed and estimated no. of drivers with period 2 accident counts = Ø | | 1 | | 2 | | 3 | | 4 | | 5 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ø | 45Ø54 | 45249.8 | 6917 | 6781.8 | 732 | 729.1 | 72 | 68.1 | 14 | 5.9 | 1 | Ø.5 |
| 1 | 8265 | 7958.7 | 15Ø3 | 1711.2 | 246 | 239.7 | 39 | 27.6 | 2 | 2.8 | 1 | Ø.3 |
| 2 | 968 | 1ØØ4.1 | 224 | 281.3 | 49 | 48.6 | 6 | 6.6 | 3 | Ø.8 | Ø | Ø.1 |
| 3 | 12Ø | 11Ø.Ø | 37 | 38.Ø | 8 | 7.8 | Ø | 1.2 | Ø | Ø.2 | Ø | Ø.Ø |
| 4 | 15 | 11.1 | 8 | 4.6 | 1 | 1.1 | 1 | Ø.2 | Ø | Ø.Ø | Ø | Ø.Ø |
| 5 | 3 | 1.1 | Ø | Ø.5 | 1 | Ø.1 | Ø | Ø.Ø | Ø | Ø.Ø | Ø | Ø.Ø |

TABLE A4.13: 2-PERIOD ACCIDENT FREQUENCIES FOR FEMALES AGED 21-25 YEARS
(Period 1: Mean=Ø.Ø861, Var(x)=Ø.Ø9Ø1; Period 2: Mean=Ø.Ø779)

| Per. 1 Accs. | Observed and estimated no. of drivers with period 2 accident counts = Ø | | 1 | | 2 | | 3 | | 4 | | 5 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ø | 5Ø331 | 5Ø337.8 | 3592 | 36Ø6.2 | 219 | 198.Ø | 5 | 9.8 | 1 | Ø.5 | 1 | Ø.Ø |
| 1 | 4Ø31 | 3988.1 | 41Ø | 437.8 | 24 | 32.4 | 1 | 2.Ø | 4 | Ø.1 | Ø | Ø.Ø |
| 2 | 226 | 242.1 | 39 | 35.8 | 6 | 3.3 | 1 | Ø.2 | Ø | Ø.Ø | Ø | Ø.Ø |
| 3 | 16 | 13.2 | 3 | 2.5 | Ø | Ø.3 | Ø | Ø.Ø | Ø | Ø.Ø | Ø | Ø.Ø |
| 4 | Ø | Ø.7 | 1 | Ø.2 | Ø | Ø.Ø | Ø | Ø.Ø | Ø | Ø.Ø | Ø | Ø.Ø |
| 5 | Ø | Ø.Ø | Ø | Ø.Ø | Ø | Ø.Ø | Ø | Ø.Ø | Ø | Ø.Ø | Ø | Ø.Ø |

TABLE A4.14: 2-PERIOD ACCIDENT FREQUENCIES FOR MALES AGED 26-30 YEARS
(Period 1: Mean=0.1608, Var(x)=0.1800; Period 2: Mean=0.1452)

| Per. 1 Accs. | Observed and estimated no. of drivers with period 2 accident counts = 0 | | 1 | | 2 | | 3 | | 4 | | 5 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 49857 | 50094.0 | 6121 | 5926.5 | 615 | 611.0 | 52 | 59.9 | 11 | 5.7 | 0 | 0.5 |
| 1 | 6840 | 6562.8 | 1205 | 1353.3 | 165 | 199.0 | 28 | 25.3 | 4 | 3.0 | 1 | 0.3 |
| 2 | 708 | 749.3 | 203 | 220.4 | 39 | 42.1 | 10 | 6.6 | 3 | 0.9 | 0 | 0.1 |
| 3 | 73 | 81.3 | 32 | 31.1 | 3 | 7.3 | 1 | 1.4 | 0 | 0.2 | 0 | 0.0 |
| 4 | 10 | 8.6 | 4 | 4.0 | 7 | 1.1 | 0 | 0.2 | 0 | 0.0 | 0 | 0.0 |
| 5 | 2 | 0.9 | 0 | 0.5 | 1 | 0.2 | 1 | 0.0 | 1 | 0.0 | 0 | 0.0 |

TABLE A4.15: 2-PERIOD ACCIDENT FREQUENCIES FOR FEMALES AGED 26-30 YEARS
(Period 1: Mean=0.0658, Var(x)=0.0692; Period 2: Mean=0.0659)

| Per. 1 Accs. | Observed and estimated no. of drivers with period 2 accident counts = 0 | | 1 | | 2 | | 3 | | 4 | | 5 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 57888 | 57922.2 | 3463 | 3460.2 | 213 | 185.0 | 8 | 9.5 | 1 | 0.5 | 0 | 0.0 |
| 1 | 3505 | 3449.8 | 340 | 368.8 | 13 | 28.4 | 2 | 1.9 | 1 | 0.1 | 0 | 0.0 |
| 2 | 181 | 183.9 | 23 | 28.3 | 0 | 2.9 | 2 | 0.2 | 0 | 0.0 | 0 | 0.0 |
| 3 | 8 | 9.4 | 3 | 1.9 | 1 | 0.2 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 |
| 4 | 1 | 0.5 | 0 | 0.1 | 0 | 0.0 | 1 | 0.0 | 0 | 0.0 | 0 | 0.0 |
| 5 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 |

TABLE A4.16: 2-PERIOD ACCIDENT FREQUENCIES FOR MALES AGED 31-35 YEARS
(Period 1: Mean=0.1495, Var(x)=0.1635; Period 2: Mean=0.1394)

| Per. 1 Accs. | Observed and estimated no. of drivers with period 2 accident counts = 0 | | 1 | | 2 | | 3 | | 4 | | 5 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 39864 | 39963.9 | 4803 | 4719.6 | 443 | 452.8 | 35 | 40.1 | 2 | 3.4 | 1 | 0.3 |
| 1 | 5202 | 5062.6 | 934 | 971.4 | 100 | 129.0 | 21 | 14.6 | 3 | 1.5 | 0 | 0.1 |
| 2 | 484 | 521.0 | 114 | 138.4 | 24 | 23.5 | 4 | 3.2 | 3 | 0.4 | 0 | 0.0 |
| 3 | 42 | 49.5 | 19 | 16.8 | 5 | 3.5 | 3 | 0.6 | 0 | 0.1 | 1 | 0.0 |
| 4 | 8 | 4.5 | 2 | 1.9 | 1 | 0.5 | 1 | 0.1 | 1 | 0.0 | 0 | 0.0 |
| 5 | 1 | 0.4 | 0 | 0.2 | 2 | 0.1 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 |

TABLE A4.17: 2-PERIOD ACCIDENT FREQUENCIES FOR FEMALES AGED 31-35 YEARS
(Period 1: Mean=0.0635, Var(x)=0.0673; Period 2: Mean=0.0687)

| Per. 1 Accs. | Observed and estimated no. of drivers with period 2 accident counts = 0 | | 1 | | 2 | | 3 | | 4 | | 5 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 50866 | 50950.5 | 3216 | 3118.1 | 166 | 183.4 | 11 | 10.6 | 0 | 0.6 | 0 | 0.0 |
| 1 | 2961 | 2886.0 | 281 | 339.5 | 25 | 29.5 | 3 | 2.3 | 0 | 0.2 | 0 | 0.0 |
| 2 | 142 | 157.1 | 31 | 27.3 | 3 | 3.2 | 0 | 0.3 | 0 | 0.0 | 0 | 0.0 |
| 3 | 11 | 8.4 | 2 | 1.9 | 0 | 0.3 | 1 | 0.0 | 0 | 0.0 | 0 | 0.0 |
| 4 | 1 | 0.4 | 0 | 0.1 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 |
| 5 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 |

**TABLE A4.18: 2-PERIOD ACCIDENT FREQUENCIES FOR MALES AGED 36-40 YEARS**
(Period 1: Mean=0.1476, Var(x)=0.1641; Period 2: Mean=0.1381)

| Per. 1 Accs. | Observed and estimated no. of drivers with period 2 accident counts = 0 | | 1 | | 2 | | 3 | | 4 | | 5 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 20440 | 20460.3 | 2339 | 2323.8 | 227 | 231.7 | 17 | 22.0 | 2 | 2.0 | 0 | 0.2 |
| 1 | 2545 | 2483.8 | 487 | 495.4 | 64 | 70.7 | 9 | 8.7 | 0 | 1.0 | 0 | 0.1 |
| 2 | 213 | 264.7 | 77 | 75.5 | 20 | 14.0 | 1 | 2.1 | 0 | 0.3 | 0 | 0.0 |
| 3 | 34 | 26.9 | 12 | 10.0 | 6 | 2.3 | 1 | 0.4 | 3 | 0.1 | 0 | 0.0 |
| 4 | 0 | 2.7 | 2 | 1.2 | 0 | 0.3 | 1 | 0.1 | 0 | 0.0 | 0 | 0.0 |
| 5 | 0 | 0.3 | 0 | 0.1 | 1 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 |

**TABLE A4.19: 2-PERIOD ACCIDENT FREQUENCIES FOR FEMALES AGED 36-40 YEARS**
(Period 1: Mean=0.0699, Var(x)=0.0732; Period 2: Mean=0.0671)

| Per. 1 Accs. | Observed and estimated no. of drivers with period 2 accident counts = 0 | | 1 | | 2 | | 3 | | 4 | | 5 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 29255 | 29224.5 | 1757 | 1792.2 | 100 | 92.5 | 2 | 4.5 | 1 | 0.2 | 0 | 0.0 |
| 1 | 1845 | 1868.4 | 218 | 192.8 | 7 | 14.0 | 3 | 0.9 | 0 | 0.1 | 0 | 0.0 |
| 2 | 98 | 100.5 | 18 | 14.6 | 2 | 1.4 | 1 | 0.1 | 0 | 0.0 | 0 | 0.0 |
| 3 | 5 | 5.1 | 1 | 0.9 | 0 | 0.1 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 |
| 4 | 0 | 0.2 | 0 | 0.1 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 |
| 5 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 |

TABLE A4.20: 2-PERIOD ACCIDENT FREQUENCIES FOR MALES AGED 41-50 YEARS
(Period 1: Mean=0.1324, Var(x)=0.1505; Period 2: Mean=0.1285)

| Per. 1 Accs. | Observed and estimated no. of drivers with period 2 accident counts = 0 | | 1 | | 2 | | 3 | | 4 | | 5 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 24587 | 24773.9 | 2680 | 2507.1 | 238 | 258.0 | 26 | 26.7 | 4 | 2.8 | 0 | 0.3 |
| 1 | 2740 | 2582.7 | 470 | 531.5 | 66 | 82.5 | 7 | 11.4 | 3 | 1.5 | 1 | 0.2 |
| 2 | 262 | 273.8 | 70 | 85.0 | 7 | 17.6 | 1 | 3.1 | 0 | 0.5 | 0 | 0.1 |
| 3 | 24 | 29.2 | 9 | 12.1 | 4 | 3.1 | 0 | 0.7 | 1 | 0.1 | 0 | 0.0 |
| 4 | 1 | 3.1 | 1 | 1.6 | 0 | 0.5 | 0 | 0.1 | 0 | 0.0 | 0 | 0.0 |
| 5 | 1 | 0.3 | 2 | 0.2 | 3 | 0.1 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 |

TABLE A4.21: 2-PERIOD ACCIDENT FREQUENCIES FOR FEMALES AGED 41-50 YEARS
(Period 1: Mean=0.0624, Var(x)=0.0664; Period 2: Mean=0.0593)

| Per. 1 Accs. | Observed and estimated no. of drivers with period 2 accident counts = 0 | | 1 | | 2 | | 3 | | 4 | | 5 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 31084 | 31136.3 | 1677 | 1639.0 | 97 | 88.3 | 0 | 4.8 | 1 | 0.3 | 0 | 0.0 |
| 1 | 1783 | 1722.8 | 155 | 185.6 | 10 | 15.1 | 2 | 1.1 | 0 | 0.1 | 0 | 0.0 |
| 2 | 84 | 97.5 | 10 | 15.9 | 2 | 1.7 | 0 | 0.2 | 0 | 0.0 | 0 | 0.0 |
| 3 | 7 | 5.6 | 2 | 1.2 | 0 | 0.2 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 |
| 4 | 1 | 0.3 | 0 | 0.1 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 |
| 5 | 1 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 |

TABLE A4.22: 2-PERIOD ACCIDENT FREQUENCIES FOR MALES AGED 51-60 YEARS
(Period 1: Mean=0.1196, Var(x)=0.1264; Period 2: Mean=0.1099)

| Per. 1 Accs. | Observed and estimated no. of drivers with period 2 accident counts = 0 | | 1 | | 2 | | 3 | | 4 | | 5 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 12119 | 12041.9 | 1108 | 1193.3 | 101 | 87.3 | 6 | 5.6 | 0 | 0.3 | 0 | 0.0 |
| 1 | 1253 | 1297.7 | 206 | 189.9 | 26 | 18.4 | 7 | 1.5 | 0 | 0.1 | 0 | 0.0 |
| 2 | 106 | 103.3 | 32 | 20.0 | 2 | 2.4 | 0 | 0.2 | 0 | 0.0 | 0 | 0.0 |
| 3 | 4 | 7.2 | 1 | 1.7 | 1 | 0.3 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 |
| 4 | 0 | 0.5 | 0 | 0.1 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 |
| 5 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 |

TABLE A4.23: 2-PERIOD ACCIDENT FREQUENCIES FOR FEMALES AGED 51-60 YEARS
(Period 1: Mean=0.0557, Var(x)=0..0598; Period 2: Mean=0.0522)

| Per. 1 Accs. | Observed and estimated no. of drivers with period 2 accident counts = 0 | | 1 | | 2 | | 3 | | 4 | | 5 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 14873 | 14867.0 | 672 | 680.2 | 42 | 36.0 | 1 | 2.0 | 0 | 0.1 | 0 | 0.0 |
| 1 | 715 | 725.3 | 76 | 76.7 | 10 | 6.4 | 0 | 0.5 | 0 | 0.0 | 0 | 0.0 |
| 2 | 52 | 40.9 | 4 | 6.8 | 0 | 0.8 | 0 | 0.1 | 0 | 0.0 | 0 | 0.0 |
| 3 | 1 | 2.4 | 0 | 0.5 | 0 | 0.1 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 |
| 4 | 0 | 0.1 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 |
| 5 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 |

TABLE A4.24: 2-PERIOD ACCIDENT FREQUENCIES FOR MALES AGED > 6Ø YEARS
(Period 1: Mean=Ø.1212, Var(x)=Ø.1392; Period 2: Mean=Ø.1ØØ6)

| Per. 1 Accs. | Observed and estimated no. of drivers with period 2 accident counts = Ø | | 1 | | 2 | | 3 | | 4 | | 5 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ø | 6456 | 649Ø.4 | 558 | 513.2 | 35 | 45.1 | 2 | 4.1 | Ø | Ø.4 | Ø | Ø.Ø |
| 1 | 641 | 618.6 | 99 | 1Ø8.8 | 16 | 14.8 | 1 | 1.8 | Ø | Ø.2 | Ø | Ø.Ø |
| 2 | 63 | 65.6 | 17 | 17.9 | Ø | 3.3 | Ø | Ø.5 | Ø | Ø.1 | Ø | Ø.Ø |
| 3 | 6 | 7.2 | 3 | 2.7 | 2 | Ø.6 | Ø | Ø.1 | Ø | Ø.Ø | Ø | Ø.Ø |
| 4 | 1 | Ø.8 | 2 | Ø.4 | Ø | Ø.1 | Ø | Ø.Ø | Ø | Ø.Ø | Ø | Ø.Ø |
| 5 | Ø | Ø.1 | Ø | Ø.1 | Ø | Ø.Ø | Ø | Ø.Ø | Ø | Ø.Ø | Ø | Ø.Ø |

TABLE A4.25: 2-PERIOD ACCIDENT FREQUENCIES FOR FEMALES AGED > 6Ø YEARS
(Period 1: Mean=Ø.Ø572, Var(x)=Ø.Ø587; Period 2: Mean=Ø.Ø597)

| Per. 1 Accs. | Observed and estimated no. of drivers with period 2 accident counts = Ø | | 1 | | 2 | | 3 | | 4 | | 5 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ø | 7112 | 7111.8 | 4Ø6 | 4Ø3.2 | 15 | 16.6 | Ø | Ø.6 | Ø | Ø.Ø | Ø | Ø.Ø |
| 1 | 382 | 386.3 | 33 | 31.9 | 3 | 1.7 | Ø | Ø.1 | Ø | Ø.Ø | Ø | Ø.Ø |
| 2 | 18 | 15.3 | 1 | 1.7 | Ø | Ø.1 | Ø | Ø.Ø | Ø | Ø.Ø | Ø | Ø.Ø |
| 3 | Ø | Ø.5 | Ø | Ø.1 | Ø | Ø.Ø | Ø | Ø.Ø | Ø | Ø.Ø | Ø | Ø.Ø |
| 4 | Ø | Ø.Ø | Ø | Ø.Ø | Ø | Ø.Ø | Ø | Ø.Ø | Ø | Ø.Ø | Ø | Ø.Ø |
| 5 | Ø | Ø.Ø | Ø | Ø.Ø | Ø | Ø.Ø | Ø | Ø.Ø | Ø | Ø.Ø | Ø | Ø.Ø |